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HUMAN RELIABILITY PREDICTION SYSTEM USER'S MANUAL

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Human Reliability Prediction System User's Manual.

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1.0 INTRODUCTION

1.1 Background

The Human Reliability Prediction System Program was initiated by the Advanced Development Objective, 43-13X. The objective of this program was to develop a technology for predicting and demonstrating the system effectiveness parameters of combined man-machine systems. Specific parameters, such as system mission reliability and availability, and design oriented measures, such as human and equipment mean time between failure (MTBF) and mean time to repair (MTTR), were considered.

Before this program, no tools existed for measuring the impact of human reliability on system performance, and there was no effective procedure for predicting human reliability in a weapons systems environment.

Project W43 13X was established in FY 69. The Chief of Naval Material designated the Naval Air Systems Command (NAVAIR) as the Principal Development Activity and assigned supporting responsibilities to the Naval Ships Systems Command (NAVSHIPS) and other Navy organizations. In NAVAIR, the project was assigned to AIR 303.

The management responsibility for the Human Reliability Prediction System was given to Naval Sea Systems Command (NAVSEA). The project team consisted of personnel from Naval Underwater Systems Center (NUSC), Applied Psychological Services, and Tracor. These team members have developed a set of procedural tools which can be used by project managers to evaluate combined human, system, and equipment reliability and maintainability.

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1.2 Available Tools and Models

The Human Reliability Program has sponsored the development of a number of techniques for estimating the impact of human performance on system performance, reliability, and maintainability (see figure 1-1). The program has developed a set of simulation and empirical models based on an extensive analysis of fleet maintenance data and a concept of operational reliability which incorporates human and equipment factors.

1.2.1 Simulation Models. The simulation models (Siegel-Wolf), developed by Applied Psychological Services Wayne, Pa., permit human, equipment, and system reliability; availability; and MTTR to be estimated as a function of human proficiency, system design, and ships environmental parameters. An example of the results obtained by these models is presented in figure 1-2.

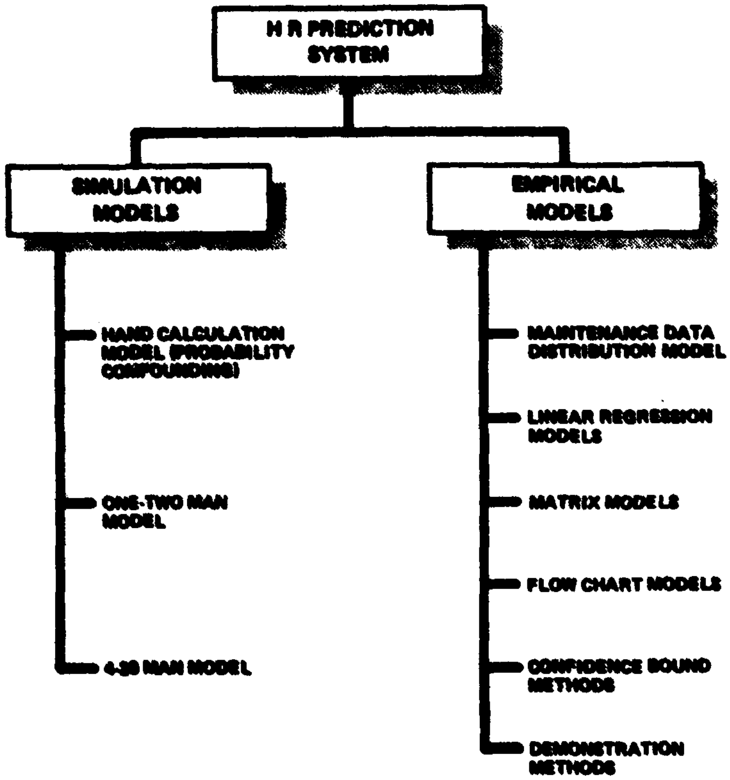

Figure 1-1. Human Reliability Prediction System Tools and Models

1.2.1.1 *Hand Calculation Model for Probability of Correcting a Malfunction.* This model provides a relatively simple hand procedure for calculating the probability of correcting a malfunction. A set of appropriate input factors is selected from the following list:

- Mental activity factor
- Physical repair activity
- Instruction factor
- Safety procedures
- Personnel management relationships
- Equipment operation
- Use of reference materials
- Equipment inspection

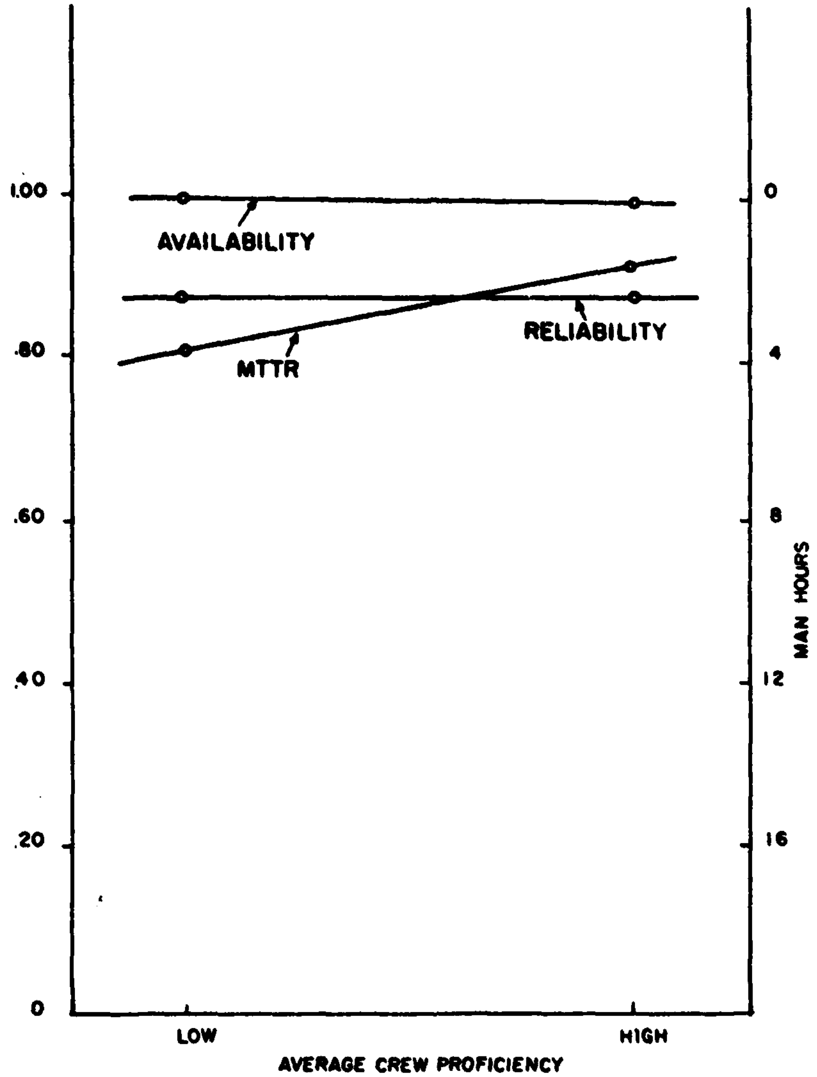

Figure 1-2. System MTTR (right scale), and Reliability and Availability (left scale) as a Function of Average Crew Proficiency and Manning Level

The probability of successful completion of each of these factors is determined, and the probability of correcting the malfunction is computed by multiplying these probabilities in the appropriate manner. Both series and parallel operations can be handled.

The methodology for computing the electronic maintenance factors listed above was developed based on data obtained from a fleet sample of 533 technicians.

1.2.1.2 One-Two Man Simulation Model for Calculating Malfunction Correction Time. A computer simulation model (figure 1-3) was developed to predict malfunction correction time. This model uses the same input data as the hand calculation procedure discussed previously. The model computes the time required to complete the actions measured by each of the factors and combines them to compute overall malfunction correction time (see figure 1-4).

This model was validated using extensive data on the AN/URC-35 and AN/APS-115 radio systems. The accuracy of this computational technique was found to be excellent.

1.2.1.3 Human and System Reliability Simulation Model (4 to 20 Men). This model simulates the behavior of a self-contained system manned by from 4 to 20 persons on missions which may vary from 1 to 30 days. This model can simulate the performance of as many as 80 jobs per day. Teams of up to 20 persons can be simulated along with the repairs of a maximum of 20 different equipments.

The typical data for this model are as follows:

- Number of men holding each rank (pay grade) and specialty (rating)
- Body weight
- Average proficiency in primary and secondary specialty
- Average work pace
- Average physical capability
- Average man's physical capability after a full work day and its effects on subsequent tasks performed.

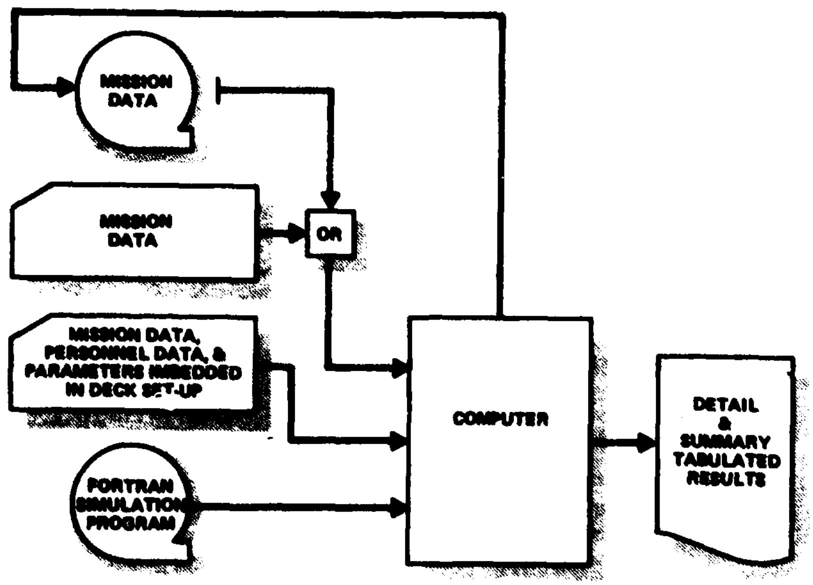

Figure 1-3. Computer Simulator System

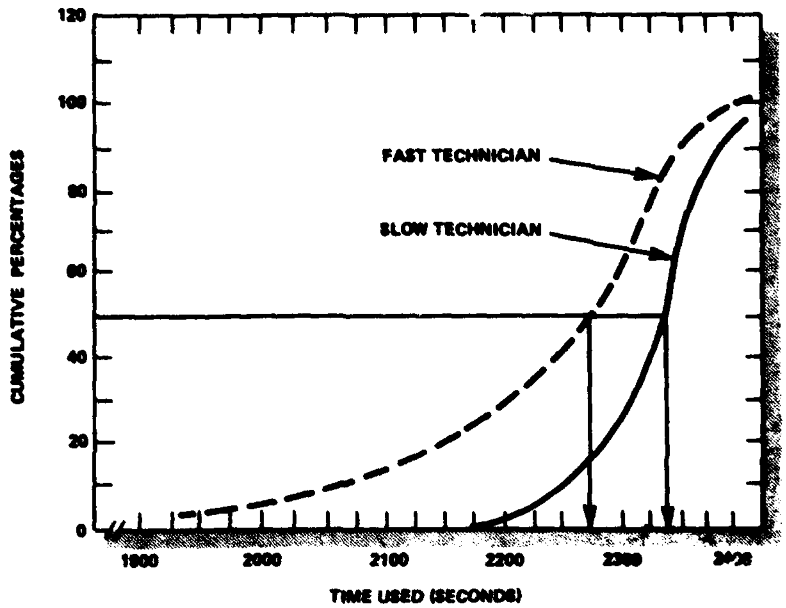

Figure 1-4. Predicted Malfunction Correction Time (Single Technician)

The equipment input data includes data such as:

- Equipment and failure rate
- Average repair time
- Standard deviation of repair time
- Number of men required to accomplish repair by type

The program calculates:

- Human reliability, availability, and MTTR
- Equipment reliability, availability, and MTTR
- System reliability, availability, and MTTR
- A variety of other parameters such as stress, fatigue, percent work completed, percent needing touchup, time for task completion, etc.

1.2.2 *Empirical Models.* The empirical models were developed, by Tracor, from fleet maintenance data on the AN/SQS-26 (CX) sonar. These models provide a simple means of relating repair time, maintenance man-hours, and maintenance man experience (see figure 1-5). An analysis of the data suggested a new parameter, called maintenance power, which tied repair time and experience together. Maintenance power is equal to the product of maintenance man experience and time spent on a repair; it was shown that

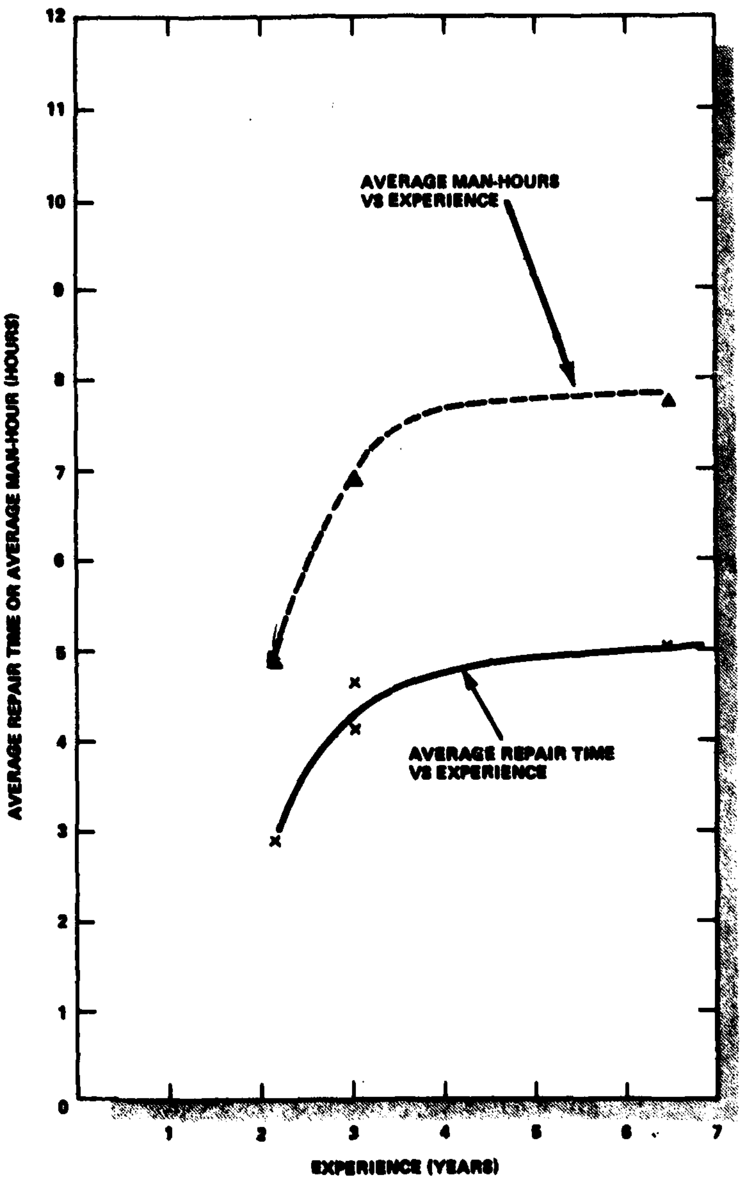

Figure 1-5. Average Repair Time and Man Hours Versus Experience

a simple relationship exists between maintenance power and the other parameters as shown in figure 1-6. This empirical model is useful to system designers during advanced development for making preliminary estimates of system MTTR, manning levels, and experience levels. Data for these studies were obtained by the Naval Weapons Engineering Support Agency (NAVWESA) under the sponsorship of NAVSEA. The specific models developed are described as follows:

- Lognormal distribution models for each major category of maintenance data
- Linear regression models relating the repair time to the new parameter, maintenance power
- A simple prediction technique based on lognormal assumptions
- A multiple repairman man-hour and repair time prediction model that employs matrix equations which incorporate repairman experience effects
- A flow chart maintainability prediction procedure that would overcome the weakness of MIL-HDBK-472 Procedure II and bridge the gap between theoretical maintainability prediction and the actual demonstration

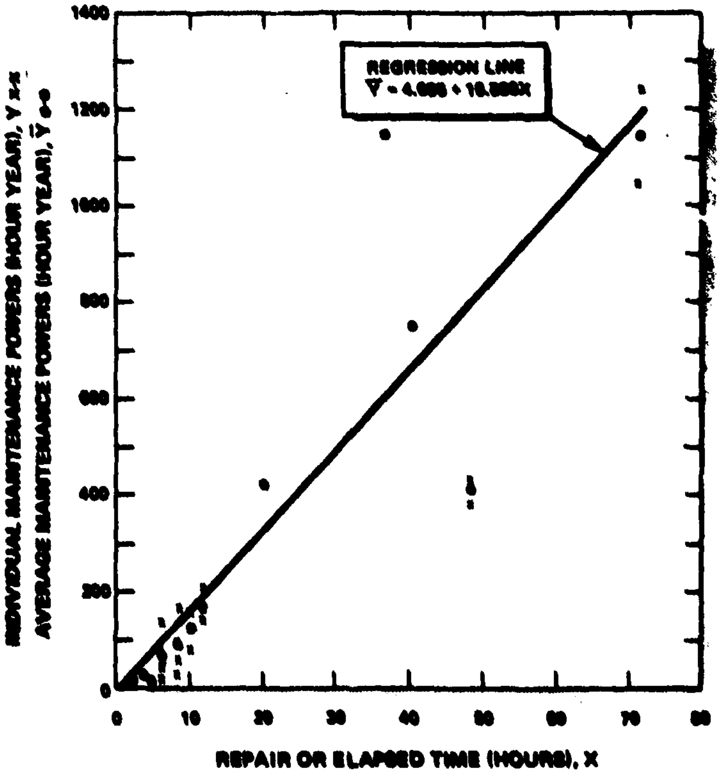

Figure 1-6. Maintenance Power Versus Repair Time

- Two methods of estimating the confidence bounds for variates that are roughly lognormally distributed (The first method predicts confidence bounds that account for parameter estimate variations, and the second method predicts confidence bounds that account for noise effects in the lognormal distribution.)

- Man-hour, repair time, and number of men per repair test demonstration methods

1.2.3 *Allocation Model.* The program also has developed a methodology for maximizing the operational reliability of man-machine systems. This model can be solved by means of standard dynamic programming techniques – it makes use of the outputs of each of the models discussed previously. The model is unique in that it permits the interactions of all of the major parameters describing man-machine interactions and their effect on operational reliability to be computed.

1.3 Measures of Effectiveness

A set of relationships for computing human, equipment, and system availability, reliability, MTTR, and MTBF was developed and incorporated into the 4 to 20 man simulation model described in section 4. These equations are listed below. The computer names of the input variables of these equations are provided.

1. *Human Reliability*

$$HUMAN\ RELIABILITY = 1 - \frac{No.\ of\ failures}{No.\ of\ attempts} \quad (1\text{-}1)$$

2. *Human Availability*

$$HUMAN\ AVAILABILITY = 1 - \frac{Time\ lost\ or\ unmanned\ hours}{Total\ mission\ manhours} \quad (1\text{-}2)$$

3. *Human MTTR*

$$HUMAN\ MTTR = \frac{Total\ time\ of\ second\ try\ successes}{No.\ of\ second\ try\ successes} \quad (1\text{-}3)$$

4. *Equipment Reliability*

$$EQUIPMENT\ RELIABILITY = 1 - \frac{Total\ no.\ of\ failures\ during\ mission}{No.\ of\ missions \times Number\ of\ equipments} \quad (1\text{-}4)$$

5. *Equipment Availability*

$$EQUIPMENT\ AVAILABILITY = \frac{\text{Equipment up time}}{\text{Total mission time x No. of equipments}} \qquad (1\text{-}5)$$

6. *Equipment MTBF*

$$EQUIPMENT\ MTBF = \frac{\Sigma \text{ times between failures}}{\text{No. of failures}}$$

$$= \frac{\text{Mission time x down time}}{\text{No. of failures}} \qquad (1\text{-}6)$$

7. *Equipment MTTR*

$$EQUIPMENT\ MTTR = \frac{\text{Total repair times for all missions}}{\text{No. of repairs}} \qquad (1\text{-}7)$$

8. *System Reliability*

$$SYSTEM\ RELIABILITY = 1 - \frac{\text{No. of equipment failures + No. of people failures}}{\text{Iterations x No. of equip + Human attempts}} \qquad (1\text{-}8)$$

9. *System Availability*

$$SYSTEM\ AVAILABILITY = 1 - \frac{\text{System down time}}{\text{Mission time}} \qquad (1\text{-}9)$$

10. System MTTR

$$\text{SYSTEM MTTR} = \frac{\Sigma \text{ time for repairs} + \Sigma \text{ time for second try successes}}{\text{No. of repairs} + \text{No. of second try successes}} \quad (1\text{-}10)$$

2.0 PROBABILITY COMPOUNDING (HAND CALCULATION)

2.1 Introduction

The probability compounding method of predicting human reliability provides a means of calculating the probability that a particular maintenance technician, or group of maintenance technicians, will successfully accomplish the sequence of tasks required to correct a particular malfunction on a given equipment or system. The method provides for hand computation of individual or group reliability indices. In section 3 this basic method is expanded into a computer simulation technique for predicting the time it will take to correct the malfunction. These predictions are based on a magnitude estimate of the ratio of the number of unusally effective to the number of unusually ineffective performances obtained in a sample of each of the required tasks. The probability compounding procedure involves the following steps as illustrated in figure 2-1.

- Multidimensional scaling
- Individual performance index computations
- Reliability index computation

These steps are discussed in detail in the following paragraphs. The probability compounding method is directly applicable to any activity which consists of a sequence of events. Therefore, it can also be used to compute human operator reliability. These techniques are discussed in the later sections of this user's manual.

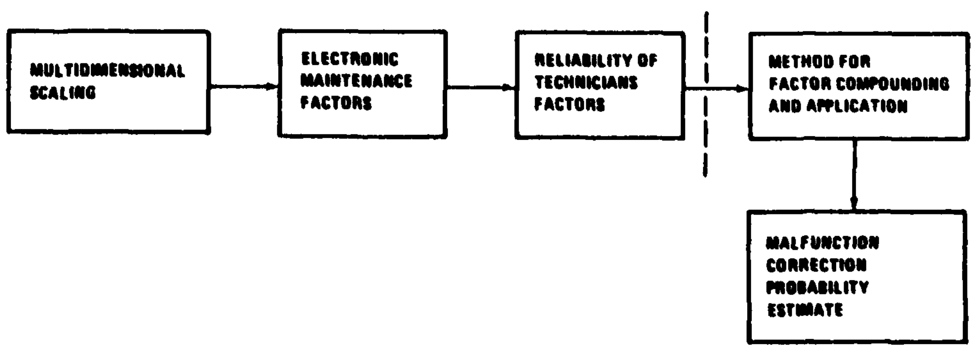

Figure 2-1. Flow of Events in Maintenance Technician Reliability Program

2.2 Multidimensional Scaling

Multidimensional scaling is a technique for identifying all of the job factors or tasks involved in the maintenance, servicing, and repair of the equipment or system. In implementing the human reliability prediction system, multidimensional scaling analyses have been performed to identify the complete spectrum of tasks and requirements involved in the maintenance of electronic equipments or systems. Equivalent factors have yet to be derived for mechanical systems.

To determine the structure of the job of the electronic maintenance technician, Siegel and Schultz (1963) performed a multidimensional scaling analysis of the job of electronic maintenance by naval technicians. The consensus of Fleet personnel interviewed indicated that the job of the technician was best described by some 29 different tasks. Examples of tasks were: using schematics for complex circuits and troubleshooting/isolating malfunctions in avionic equipments. The 29 tasks performed by both supervisory and line personnel constituted the sample which provided the basic data for the analysis. Sixty-five subjects distributed over 14 separate maintenance units were involved. The data was factor analyzed by the principal components method with rotation according to the equamax criterion (Saunders, 1962). Nine factors emerged. These factors were named: Electro-cognition (EC), Electro-repair (ER), Instruction (I), Electro-safety (ES), Personnel Relationships (PR), Electronic Circuit Analysis (ECA), Equipment Operation (EO), Using Reference Materials (URM), and Equipment Inspection (EI). These factors are fully defined in table 2-1. Numerical estimates are given in section 3. These should be used in all predictions.

Table 2-1. Definition of Factors

1.	Electro-cognition	This factor is associated with any routine mental activity involved in the troubleshooting acts. It includes the mental formulation of simple hypotheses regarding the cause of a malfunction, the mental synthesis of elementary cause-effect relationships, logical thinking of a routine nature, and the integration of test results with pretest hypotheses. Simple sequential tests do not involve electro-cognition. For example, continuity tests would not involve this category. This is a "how to make it work" factor as opposed to electronic circuit analysis, which is a "why it doesn't work" factor. Tasks which might involve electro-cognition are: • Making logic changes in a data processing unit • Comparing an output waveform to an illustration in a technical manual • Observing fault lights and inferring module to be replaced
2.	Electro-repair	This factor includes the motor and manipulative aspects of physically repairing a component which has failed. It does not include module or component replacement, but does include module or component repair. Examples of tasks including electro-repair are: • Replacing a broken solder joint • Adjusting the contacts on a relay
3.	Instruction	This factor involves teaching others how to inspect, repair, operate, or maintain electronic equipments. Examples of tasks involving this factor are: • Instructing another technician on how to use test equipment • Instructing a subordinate on how to perform a test or repair act • Instructing an operator on how to work an equipment

Table 2.1. Definition of Factors (Continued)

4.	Electro-safety	This factor involves implementation of special safety procedures to minimize the possibility of additional equipment damage. An example task involving this factor is: • Observing high voltage protection instructions on equipment
5.	Personnel Relationships	This factor includes the management and supervisory aspects of maintenance organization functions. Examples of tasks involving this factor are: • Supervising the operation/inspection/maintenance of an electronic equipment • Assigning personnel to an electronic repair • Developing a repair schedule
6.	Electronic Circuit Analysis	This factor is purely mental in nature. It includes the application of electronic principles to the correction of a fault. Electronic principles include the selection and use of circuit formulae and the application of the results of calculations, and application of principles of electrical/electronic diagnostic techniques. This factor is different from the electro-cognition factor in that electro-cognition is almost directly effect-cause related, whereas electronic circuit analysis involves more sophisticated consideration of intervening processes. For example, if in the case of a faulty output, the technician can decide that either module A, B, or C is malfunctioning and that he can complete the repair by sequential replacement of modules until the correct output is obtained, then the factor involved is electro-cognition. On the other hand, if the technician must perform a test on each of A, B, and C and then apply electronic theory to determine the faulty module, then electronic circuit analysis is involved. Electronic circuit analysis might also be involved in certain aspects of failure reporting. Examples of electronic circuit analysis are: • Determining why an oscillator yields an improper frequency response • Determining why the time delay of a timing circuit is too long • Determining why a power supply goes into an over-voltage shutdown mode
7.	Equipment Operation	This factor involves the operation or exercise of prime equipment and electrical and electronics test equipment. Examples of this factor are: • Employing repaired equipment • Using an oscilloscope

8.	Using Reference Materials	This factor includes the use of supporting documentation. The use of schematics and block diagrams is included under either electro-cognition or electronics circuit analysis.
9.	Equipment Inspection	This factor includes inspections of electronic equipment, including those inspections and examinations required after performing a correction or repair to the equipment.

2.3 Performance Indices

To apply the prediction system to a particular maintenance organization, each maintenance technician must be rated in each of the tasks identified in the multidimensional scaling analysis. Individual ratings were obtained by observing and evaluating a sufficient number of performances in each job factor to provide a valid sample of the technician's capability. Estimates based on previous experience will also be used. These estimates were derived by interviewing technicians who were experienced in each job factor. In each job factor, the technician's unusually effective (UE) and unusually ineffective (UI) performances were identified. The technician's performance index (or probability of successful job performance) for each job factor was then computed by the formula:

$$\frac{\Sigma\, UE}{\Sigma\, UE + \Sigma\, UI} \tag{2-1}$$

The calculations for determining technician performance index ratings are given in example 2-1.

Example 2-1. Performance Index Calculations

Procedure	*Example*
1. Identify Σ UE and Σ UI for each job factor	1. In 25 performances on a particular job factor, technician a was rated unusually effective in six performances and unusually ineffective in one performance $\Sigma\, UE = 6$ $\Sigma\, UI = 1$
2. Compute the technician's performance index (probability of successful performance) for the job factor $\left(\frac{\Sigma\, UE}{\Sigma\, UE + \Sigma\, UI}\right)$	2. $\frac{6}{6+1} = .86$ Technician a's Performance index (probability of successful performance) = .86

In practice, the data provided in table 2-2 should be used. Performance indices need not be recomputed for each new electronic system problem.

Table 2-2. Average Technician Reliability Ratings

Job Activity	Career Field							
	EM	ET	FT	IC	RD	RM	ST	TM
Electro Cognition	.55	.83	.86	.62	.33	.63	.92	.36
Electro Repair	.78	.99	.92	.70	.30	.71	.70	.40
Instruction	.75	.95	.97	.45	.57	.95	.51	.66
Electro Safety	.60	.98	.95	.65	.92	.70	.42	.62
Personnel Relationships	.74	.70	.79	.63	.40	.77	.85	.80
Electro Circuit Analysis	.63	.90	.95	.58	.40	.65	.74	.60
Equipment Operation	.92	.85	.95	.65	.90	.85	.92	.75
Using Reference Material	.73	.90	.87	.62	.95	.92	.88	.66

EM - Electrician's mate
ET - Electronics Technician
FT - Fire Control Technician
IC - Interior Communications Electrician
RD - Radarman
RM - Radioman
ST - Sonar Tachnician
TM - Torpedoman's mate

2.4 Reliability Index Computation

Given a multidimensional scaling of the equipment or system to be maintained and a complete set of performance indices for each technician, the human reliability for a given malfunction can be computed.

A malfunction in the equipment or system will involve some (not necessarily all) of the job factors identified in the multidimensional scaling analysis. After the factors which are involved in the malfunction are determined, the maintenance technician's performance indices in those factors can be used to compute the probability that the malfunction will be successfully corrected.

The actual method of computing reliability depends upon several variables: The reliability prediction technique used will depend on the interdependencies among the job factors involved in the correction of the malfunction and with the number of technicians assigned to the problem. Another variable is the method of assignment when more than one technician is assigned to a problem—whether they work independently on different job tasks or together on the same task.

2.5 Compounding Methods

2.5.1 *Introduction.* Several different job activities and persons may be involved in the performance of a task. Successful task performance may require the successful performance of all job activities by all persons or the successful performance of only some combination of job activities. The probability of successful task performance is increased when several persons are assigned to the same task, and perform the job activity in parallel with each other. In addition, the probability of successful performance will be increased if a technician is permitted to repeat the performance or one aspect of the performance.

Siegel and Miehle (1967) presented methods for calculating overall probability of successful task accomplishment when the probability of accomplishing each of the elements of the task is known. The methods are demonstrated below. They were developed to exploit the job factors identified in the multidimensional scaling studies and personnel reliability data on each factor collected originally by Siegel and Pfeiffer and later by Siegel and Federman.

Basic concepts are expressed as follows:

Let:

s = satisfactory task performance

r_{mn} = satisfactory performance of job activity m by technician n

R_{mn} = reliability of technician n on activity m

$P_r[r_{mn}]$ = probability that statement r_{mn} is true

Thus, $P_r[r_{mn}] = R_{mn}$ and $P_r[s]$ = reliability of task performance.

Suppose performance of a task involves technician b on three job factors (3, 4, and 6) and technician g on three factors (3, 5, and 8). Both technicians perform factor 3. The condition for satisfactory task performance is:

$$s \equiv (r_{3b} \vee r_{3g}) \wedge r_{4b} \wedge r_{6b} \wedge r_{5g} \wedge r_{8g} \tag{2-2}$$

$\vee$ is a symbol for inclusive *or* (inclusive disjunction)

$\wedge$ is a symbol for *and* (conjunction)

$\equiv$ is a symbol for "is equivalent to"

We are not limited to an "and" and "or" logic. Statements could conceivably be connected by conditional or biconditional symbols. These in turn can be expressed in items of "and," "or," and negation. The negation of r_{ij} is r'_{ij}.

Electronic equipment maintenance can be performed by means of series or parallel tasks and by a single or a group of maintenance technicians. Several examples illustrating a number of different cases are given below.

2.5.2 *The Series Case.* The condition that all activities must be performed satisfactorily is expressed by joining all statements by "conjunction" ($\wedge$), s $r_{1a} \wedge r_{2a}$. This is called a *series* task.

$$P_r[s] = P_r[r_{1a} \wedge r_{2a}] = P_r[r_{1a} \mid r_{2a}]\, P_r[r_{2a}] \qquad (2\text{-}3)$$

$Pr[r_{1a} \mid r_{2a}]$ is a conditional probability which is read "the probability of r_{1a}, given r_{2a}." It is the probability that r_{1a} is true under the condition of r_{2a} being true. When the truth of r_{1a} is independent of the truth of r_{2a}, we say that r_{1a} and r_{2a} are independent statements. In this case, $P_r[s] = P_r[r_{1a}]P_r[r_{2a}]$.

Let:

$$s \Leftrightarrow r_{2a} \wedge r_{3d} \wedge r_{6a} \qquad (2\text{-}4)$$

$$\begin{aligned} P_r[s] &= P_r[r_{2a} \wedge r_{3d} \wedge r_{6d}] \\ &= P_r[r_{2a} \mid r_{3d} \wedge r_{6a}]P_r[r_{3d} \mid r_{6a}]P_r[r_{6a}] \end{aligned} \qquad (2\text{-}5)$$

If all statements are independent, this reduces to:

$$P_r[s] = P_r[r_{2a}]P_r[r_{3d}]P_r[r_{6a}] \qquad (2\text{-}6)$$

Example 2-2 demonstrates the computations involved in technician reliability prediction for a 2 series task.

Example 2-2. Series Task

Task Description

The sample task involves job factors 1 (Electro-cognition) and 2 (Electro-repair). The task is performed by technician a, and both job factors must be completed for successful completion of the task.

Mathematical Expression of the Problem

$$s \Leftrightarrow r_{1a} \wedge r_{2a} \qquad (2\text{-}7)$$

Applicable Formula

$$P_r[s] = P_r[r_{1a}]P_r[r_{2a}] \qquad (2\text{-}8)$$

Procedures

Procedure	Example
1. Determine the factors required to correct the problem	1. The malfunction involves job factors Electro-cognition (1) and Electro-repair (2) (Job factors are identified in table 2-1.)
2. Determine the technician's performance index ratings in the applicable job factors	2. Technician a is assigned to the problem. Applicable performance index ratings are: EC(1) = .86 ER(2) = .90

3. Substitute the technician's performance index ratings into the formula and compute the probability that the technician can correct the malfunction

3. $$P_r[s] = P_r[r_{1a}]\,P_r[r_{2a}]$$
$$= [.86]\ [.90]$$
$$= .774$$

Before concluding this discussion of the sample series case, it is important to note that all practical calculations assume that technician actions on each job factor are independent of the other job actions. This assumption is made because no data is available for the conditional case.

2.5.3 ***The Parallel Case.*** If the satisfactory performance of one or the other factor (or both) is required for the satisfactory performance of the task, then the task is called a parallel task. The satisfactory performance of parallel tasks is expressed as:

$$s \equiv r_{3e} \vee r_{7e} \tag{2-9}$$

In this case, job factors 3 and 7 are involved and the task is performed by technician e.

When the same job factor is performed by two technicians and acceptable performance of either technician will constitute acceptable performance for the team, the condition is expressed as:

$$s \equiv r_{3a} \vee r_{3c} \tag{2-10}$$

This condition is also referred to as a parallel performance. In the following formula, job factor 3 is performed by technicians a and c.

$$P_r[s] = P_r[r_{3a} \vee r_{3c}] = 1 - (1 - P_r[r_{3a}])(1 - P_r[r_{3c}]) \tag{2-11}$$

in the independent case.

A similar case involving three technicians is expressed as:

Let:

$$s \equiv r_{1b} \vee r_{1c} \vee r_{1g} \tag{2-12}$$

then:

$$\begin{aligned} P_r[s] &= P_r[r_{1b} \vee r_{1c} \vee r_{1g}] \\ &= 1 - (1 - P_r[r_{1b}])(1 - P_r[r_{1c}])(1 - P_r[r_{1g}]) \end{aligned} \tag{2-13}$$

in the independent case.

Examples 2-3 and 2-4 demonstrate the computations involved in reliability prediction for parallel tasks. In example 2-3, two job factors are performed by a single technician. In example 2-4, two technicians work together on one job factor.

Example 2-3 Parallel Task for Single Technician

Task Description

The sample task involves job factors 1 (Electro-cognition) and 2 (Electro-repair). The task is performed by technician a, and satisfactory completion of either job factor will constitute successful completion of the task.

Mathematical Expression of the Problem

$$s = r_{1a} \vee r_{2a} \tag{2-14}$$

Applicable formula

$$P_r[s] = 1 - (1 - P_r[r_{1a}])(1 - P_r[r_{2a}]) \tag{2-15}$$

Procedures

Procedure	Example
1. Determine the factors required to correct the problem	1. The malfunction involves job factors Electro-cognition (1) and Electro-repair (2) (Job factors are identified in table 2-1.)
2. Determine the technician's performance index ratings in the applicable job factors	2. Technician a is assigned to the problem. Applicable performance index ratings are: EC(1) = .82 ER(2) = .79
3. Substitute the technician's performance index ratings into the formula and compute the probability that the technician can correct the malfunction	3. $P_r[s] = 1 - (1 - P_r[r_{1a}])(1 - P_r[r_{2a}])$ $P_r[s] = 1 - (1 - .82)(1 - .79)$ $= 1 - (.18)(.21)$ $= 1 - .038$ $= .962$

Example 2-4. Parallel Task for Two Technicians

Task Description

The sample task involves job factor 3 (Inspection). The task is performed by technicians a and b, and satisfactory performance by either technician will result in successful completion of the task.

Mathematical Expression of the Problem

$$s = r_{3a} \vee r_{3b} \tag{2-16}$$

Applicable Formula

$$P_r[s] = 1 - (1 - P_r[r_{3a}])(1 - P_r[r_{3b}]) \qquad (2\text{-}17)$$

Procedures

Procedure	Example
1. Determine the factors required to correct the problem	1. The malfunction involves job factor 3 (Inspection) (Job factors are identified in table 2-1.)
2. Determine the technician's performance index ratings in the applicable job factors	2. Technicians a and b are assigned to the problem. Applicable performance index ratings are: a = .82, b = .88
3. Substitute the technicians' performance index ratings into the formula and compute the probability that the technicians can correct the malfunction	3. $P_r[s] = 1 - (1 - .82)(1 - .88)$ $= 1 - (.18)(.12)$ $= 1 - .022$ $= .978$

2.5.4 *Complex Tasks.* The series and parallel formulas can be extended to larger numbers of activities and performers. These formulas may be written in many forms. Some malfunctions may result in a combination of the series and parallel formulas. Examples 2-5 and 2-6 demonstrate the computations involved in complex tasks. In example 2-5 a complex task with series and parallel elements is performed by one technician. In example 2-6 two technicians work on a complex task. The technicians work together on some of the tasks and independently on others.

Example 2-5. Complex Task Performed by One Technician

Task Description

The sample task involves the following job factors:

- 1 (Electro-cognition)
- 2 (Electro-repair)
- 3 (Inspection)
- 4 (Electro-safety)
- 5 (Personnel relationships)

The task is performed by technician a and will be considered satisfactorily completed if, and only if, either (or both) factors 1 and 2 are performed satisfactorily, either (or both) factors 3 and 4 are performed satisfactorily, and factor 5 is performed satisfactorily.

Mathematical Expression of the Problem

$$s \equiv (r_{1a} \vee r_{2a}) \wedge (r_{3a} \vee r_{4a}) \wedge r_{5a} \qquad (2\text{-}18)$$

Applicable Formula

$$P_r[s] = \left\{ 1 - (1 - P_r[r_{1a}])(1 - P_r[r_{2a}]) \right\} \left\{ 1 - (1 - P_r[r_{3a}])(1 - P_r[r_{4a}]) \right\} P_r[r_{5a}] \qquad (2\text{-}19)$$

Procedures

Procedure	Example
1. Determine the factors required to correct the problem	1. The malfunction involves job factors EC, ER, I, ES, and PR. (Job factors are identified in table 2-1.)
2. Determine the technician's performance index ratings in the applicable job factors	2. Technician a is assigned to the problem. Applicable performance index ratings are: EC (1) = .86 ES (4) = .92 ER (2) = .90 PR (5) = .79 I (3) = .82
3. Substitute the technician's performance index ratings into the formula and compute the probability that the technician can correct the malfunction	3. $P_r[s] = \{1 - (1 - .86)(1 - .90)\} \{1 - (1 - .82)(1 - .92)\} .79$ $= \{1 - (.14)(.10)\} \{1 - (.18)(.08)\} .79$ $= \{1 - .014\} \{1 - .0144\} .79$ $= .768$

Example 2-8. Complex Task Performed by More Than One Technician

Task Description

The sample task involves the following job factors:

- 1 (Electro-cognition)
- 2 (Electro-repair)
- 3 (Inspection)
- 4 (Electro-safety)
- 5 (Personnel relationships)
- 6 (Electronic circuit analysis)
- 7 (Equipment operation)
- 8 (Using reference materials)

The task is performed by technicians a and b. Technician a performs job factors 1 through 4, technician b performs job factor 5, and both technicians work together on job factors 6, 7, and 8. All job factors must be performed satisfactorily for successful completion of the task, and satisfactory performance by either technician on a particular job factor constitutes satisfactory completion of that job factor.

Mathematical Expression of the Problem

$$s = r_{1a} \wedge r_{2a} \wedge r_{3a} \wedge r_{4a} \wedge r_{5b} \wedge (r_{6a} \vee r_{6b}) \wedge (r_{7a} \vee r_{7b}) \wedge (r_{8a} \vee r_{8b}) \tag{2-20}$$

Applicable Formula

$$\begin{aligned} P_r[s] = {} & P_r[r_{1a}]\, P_r[r_{2a}]\, P_r[r_{3a}]\, P_r[r_{4a}]\, P_r[r_{5b}] \\ & \{1 - (1 - P_r[r_{6a}])(1 - P_r[r_{6b}])\} \\ & \{1 - (1 - P_r[r_{7a}])(1 - P_r[r_{7b}])\} \\ & \{1 - (1 - P_r[r_{8a}])(1 - P_r[r_{8b}])\} \end{aligned} \tag{2-21}$$

Procedures

Procedure	*Example*
1. Determine the factors required to correct the problem	1. The malfunction involves job factors EC, ER, I, ES, PR, ECA, EO, and URM (Job factors are identified in table 2-1.)
2. Determine the performance index ratings for the technicians assigned to the job	2. (see table below)
3. Substitute the technicians' performance index ratings into the formula and compute the probability that the technicians can correct the malfunction	3. (see computation below)

2\.

Factor	Technician Rating a	b
EC (1)	.86	.92
ER (2)	.90	.89
I (3)	.82	.88
ES (4)	.92	.90
PR (5)	.79	.85
ECA (6)	.88	.86
EO (7)	.91	.93
URM (8)	.95	.94

3\.

$$\begin{aligned} P_r[s] &= (.86)(.90)(.82)(.92)(.85) \\ & \quad \{1 - (1 - .88)(1 - .86)\} \\ & \quad \{1 - (1 - .91)(1 - .93)\} \\ & \quad \{1 - (1 - .95)(1 - .94)\} \\ &= (.86)(.90)(.82)(.92)(.85) \\ & \quad \{1 - (.12)(.14)\} \quad \{1 - (.09)(.07)\} \\ & \quad \{1 - (.05)(.06)\} \end{aligned}$$

$$= (.86)(.90)(.82)(.92)(.85)(1 - .0168)(1 - .0063)(1 - .003)$$

$$= (.86)(.90)(.82)(.92)(.85)(.983)(.994)(.997)$$

$$= .484$$

2.6 Summary

The probability compounding technique is summarized as follows:

- ***Multidimensional Scaling***—Perform a multidimensional scaling analysis of the equipment or system to be maintained. Determine all of the job factors involved in all phases of corrective maintenance.

- ***Personnel Evaluation***—Evaluate each maintenance technician in all of the identified job factors and develop a set of performance index ratings based on the formula:

$$\frac{\sum UE}{\sum UE + \sum UI} \tag{2-1}$$

NOTE: Performance index ratings must be recomputed periodically to to compensate for learning that takes place during repeated performances of the job factors.

- ***Problem Analysis***—Analyze the malfunction to determine the job factors involved.

- ***Personnel Assignment***—Select the maintenance technician or technicians to perform the task, and decide how they will be assigned to the task (number of technicians on each job factor, etc.).

- ***Development of Probability Compounding Formula***—Identify the relationships between the factors involved in the task, mathematically state the requirements for satisfactory completion of the task(s), and develop the formula for computing the probability of successful task completion ($P_r[s]$).

3.0 DIGITAL SIMULATION MODEL (ONE AND TWO MAN MODEL)

3.1 Introduction

The Siegel-Wolf one and two man simulation model, developed at Applied Psychological Services, permits the simulation of maintenance or operator tasks for the purpose of predicting task completion time and the probability of successful completion. The model is capable of simulating distributions for one, either one of two, and two maintenance technicians or operators working together. In addition to this data, the model also provides answers to other questions such as:

- Can an average operator be expected to successfully complete all actions required in the performance of a task within a time limit for a given operator procedure and a given machine design?
- How does success probability change for slower or faster operators and longer or shorter periods of allotted time?
- How great a stress is placed on the operator during his performance and in which portions of the task is he overloaded or underloaded?
- What is the frequency distribution of operator failures as a function of various stress tolerances and operator speeds?
- What operator proficiency is required for the system?
- How much time does one operator spend waiting for the other operator?
- What is the optimum team composition?
- How frequently is each subtask failed?
- How cohesive is the team?
- What is the expected time for task completion, considering an "average" operator? A "fast" operator? A "slow" operator? Various operator combinations?
- How can the equipment design be modified to yield improved performance?

The model may be used to predict either operator or maintenance technician performance by simply identifying the personnel as operators or technicians and the tasks as operator tasks or maintenance tasks.

3.1.1 *Simulation Program.* The simulation model is programmed in FORTRAN. The program is 2972 steps long, requires 100 bytes of core, and typical problems (typically, consisting of approximately 75 subtasks and 100 iterations) are executed in 18 seconds of central processor time.

3.1.2 *Model Operation.* Figure 3-1 summarizes the procedures for using the model and shows the outputs that are available. The model simulates the acts and behaviors of a maintenance technician (or operator) during the performance of a malfunction correction (or operator task performance). As the computer simulates the performance of the tasks required for correction of the malfunction, results are recorded indicating the areas of technician overload, failure to complete subtasks, idle time, peak stress, etc. For the purpose of predicting technician reliability, the prime concern is estimating the time it takes to complete the malfunction correction. The model records the time to complete each act, or subtask in the sequence of malfunction correction subtasks; the cumulative time for the completion of all required subtasks; and the total time involved in the malfunction correction. The model is designed to predict operator task performance or malfunction correction time on tasks requiring one and two operators or technicians, as described in the following paragraphs.

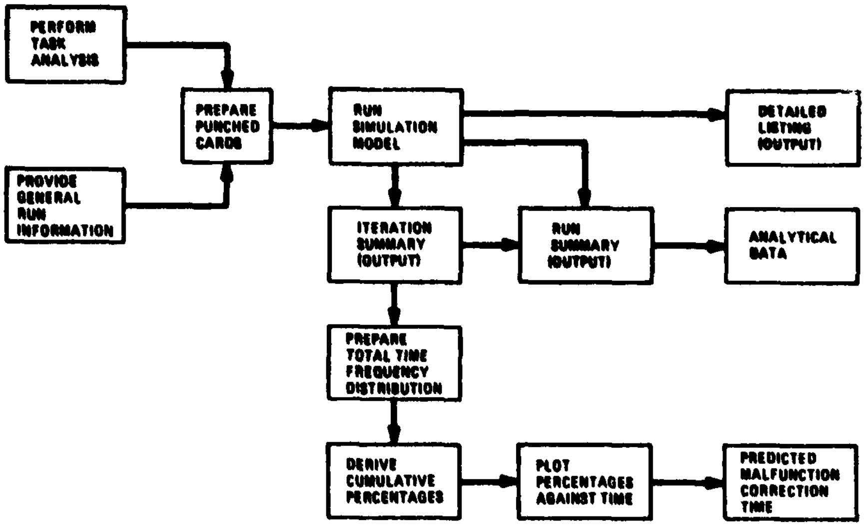

Figure 3-1. Flow Chart of Digital Simulation Model Operation

Note: All Output options may be exercised in the same simulation. They are not mutually exclusive.

3.2 Simulation Procedure (Maintenance Technicians)

The one and two man model is used to simulate malfunction correction tasks that do not require more than two maintenance technicians. The simulated tasks may be performed by one technician at a time, or by two technicians working together. The procedure for using this model to predict maintenance technician reliability is summarized as follows:

- Perform a task analysis to identify the subtasks involved in the correction of the malfunction, and prepare a sequentially numbered list of subtasks; identify the subtasks performed by each technician separately or jointly
- Prepare an input data sheet providing information about each subtask as required for the model
- Prepare a punched card for each subtask and a separate card punched to indicate the number of subtask cards prepared
- Prepare a general run information card and parameter input data cards as required
- Assemble the card deck and run the model

- Graphically summarize the data by malfunction and across malfunctions (the malfunction summaries show the estimated time to correct a particular type of malfunction; the across malfunction data summary shows the estimated time to repair for the system)

3.2.1 *Task Analysis.* A sequential list of the subtasks involved in the correction of a particular malfunction is required for the computer simulation. The list may be prepared from an available task analysis or by consultation with individuals familiar with the steps required to correct the malfunction. When a complete list of subtasks is not available, an in-depth task analysis must be performed to determine all of the steps required to correct the malfunction. The subtasks are then listed sequentially and all interrelationships noted. A sample of a subtask list is presented in table 3-1.

Table 3-1. Sample List of Subtasks

Task: Repair Filter on AN/URC-35

Subtask Number	Description	Subtask Number	Description
1.	Open drawer (AM-3007)	29.	Remove old capacitor
2.	Defeat interlock switch	30.	Remove old choke
3.	Key handset to check power	31.	Install new capacitor
4.	Check power meter	32.	Install new choke
5.	Adjust APC on module and check meter	33.	Solder wires on new capacitor
		34.	Solder wires on new choke
6.	Turn off power at set	35.	Check choke with ohmmeter
7.	Test pin 2 with ohmmeter	36.	Read ohmmeter
8.	Read ohmmeter	37.	Check capacitor with ohmmeter
9.	Manual lookup	38.	Read ohmmeter
10.	Test pin with ohmmeter	39.	Repair successful?
11.	Read ohmmeter	40.	Repair unsuccessful?
12.	Remove cable 1A2J21 on 618	41.	Walk to bulkhead and back
13.	Manual lookup	42.	Turn on power at bulkhead
14.	Test pin with ohmmeter	43.	Turn on power at set
15.	Read ohmmeter	44.	Turn Tune-Operate SW to tune
16.	Remove filter box	45.	Read meter
17.	Test for open coil with ohmmeter	46.	Remove screws from AM-3007
18.	Read ohmmeter	47.	Pull AM-3007 out to lock position
19.	Fill out requisition form for parts C39 and L10	48.	Adjust APC Adjust on module
		49.	Replace plugs and screws on filter box cover
20.	Walk to bulkhead and back		
21.	Turn off power at bulkhead	50.	Lock chassis
22.	Pull out chassis from 618 cabinet	51.	Push in chassis
		52.	Untilt chassis
23.	Tilt cabinet upward	53.	Replace chassis
24.	Unlock chassis	54.	Replace filter box
25.	Remove chassis	55.	Replace cable 1A2J21
26.	Remove plugs and screws from filter box cover	56.	Close drawer (AM-3007)
		57.	Replace screws in AM-3007
27.	Unsolder wires from capacitor	61.	Decision
28.	Unsolder wires from choke	62.	Fill out failure report

3.2.2 *Input Data Sheet Preparation.* After completion of the task analysis and preparation of the list of subtasks, enter the subtasks on the input data sheet, and fill in the required input data in the appropriate columns. A sample input data sheet is shown in figure 3-2. Table 3-2 provides a step-by-step explanation of the data required in each column of the input data sheet.

Table 3-2. Input Data Sheet Preparation

Variable	Required Input Data
Task Type Essential	Enter D for a decision subtask. The model will simulate a choice or decision made by the technician. The probabilities of the next task (i.e., success or failure) are not affected by operator factors (i.e., stress) for decision tasks.
Nonessential	Enter N for all subtasks that are not essential to the successful completion of the malfunction correction. This information allows the computer to ignore non-essential subtasks during very urgent conditions.
Precedence Task	Any subtask which must be completed by a second technician before this subtask is attempted by this technician.
Precedence Time	Time before which this subtask cannot be started.
Next Success	Identifies the number of the subtask that the technician is to perform next if he succeeds on the current subtask. If the current subtask is successfully completed, the technician will proceed to the next specified subtask. All subtasks thus can cause program branching.
Next Fail	Identifies the number of the task that the technician is to perform next if he fails the current subtask. In the example, subtask 1 follows subtask 39 if the technician was unsuccessful in repairing the malfunction. Thus, all the trouble-shooting subtasks (1 through 18) will be repeated. In the decision subtask 40, the technician decides if he was partially unsuccessful with the repair. If so, he will loop to subtask 19 and redo all the repair acts (subtasks 19 through 40).
Average Time	The average time, in seconds, required by the technician performing this subtask. There are several sources for such information.* If the average time required is not provided in the literature, then referrals to knowledgeable people and/or timing technicians as they perform the behaviors over several occasions (and averaging the values) will provide the required data. There are no time entries for decision subtasks.
Time Deviation	The average standard deviation taken around the $\bar{T}_{ij}$ for the average operator. These data are also taken from standard sources.
Success Probability	The probability that the task will be performed successfully and, therefore, that the "Next Success" task will be performed next.

Table 3-2. Input Data Sheet Preparation (Continued)

Variable	Required Input Data
Time Remaining –Essential	The time required to perform all remaining essential subtasks (including the current one) at average execution times, assuming no failures. Calculate T_{ij}^{E} by starting with the last subtask. Enter its $\bar{t}_{ij}$ in the T_{ij}^{E} column. Continue up the subtask list until the first one is reached by adding the $\bar{t}_{ij}$ for each subtask to the T_{ij}^{E} for the preceding subtask. Notice that in figure 3-2 the T_{ij} recorded alongside a decision subtask is the same as the T_{ij}^{E} for the immediately following subtask.
Time Remaining –Nonessential	The time required to perform all remaining nonessential subtasks (including the current one) at average execution times, assuming no failures. Calculate these values by entering the $\bar{t}_{ij}$ alongside the last nonessential subtask, continue entering this value until the next preceding nonessential subtask is reached, add its $\bar{t}_{ij}$ to the value that is being repeated, and continue until the first subtask is reached.

* Munger, S.J., Smith, R.W., & Payne, D. "An index of electronic equipment operability: Data store." Pittsburgh: American Institute for Research, 1962.

3.2.3 *Calculation of Essential and Nonessential Time Remaining.* In order to complete the required entries for the subtask data card, card type 3, T_{ij}^{E}, and T_{ij}^{N} (the time remaining for completion of essential and nonessential subtask elements) must be calculated by hand. The symbol T_{ij}^{E} denotes the length of time in seconds the technician "j" expects to use to complete the remaining essential subtask elements "i" in a mission. T_{ij}^{N} denotes the length of time in seconds the technician expects to use for completion of the remaining nonessential subtask elements in the mission. This time includes the current subtask element in each case. The two values are calculated independently. The procedure for calculating T_{ij}^{E} and T_{ij}^{N} are presented in the following paragraphs.

3.2.3.1 *Time Line Drawing.* Except for very simple tasks, a time line drawing should be prepared to facilitate the calculation of the T_{ij}^{E} and T_{ij}^{N} values. A hypothetical sample mission is presented in table 3-3, and its corresponding time line drawing is shown in figure 3-3. Table 3-3 includes only those data elements required to determine T_{ij}^{E} and T_{ij}^{N} values. The following notes and conventions apply to the time line drawing shown in figure 3-3.

- Times used are average subtask execution times ($\bar{t}_{ij}$).
- No random effects are considered.
- The top line in the drawing applies to technician 1, the lower line to technician 2.

TASK NUMBER 2
NUMBER OF RUNS 2 NUMBER OF ITERATIONS 100

TASK DATA FOR OPERATOR

TASK NO	TASK TYPE	NON ESS	PRECEDENCE TASK	PRECEDENCE TIME	NEXT-TASK SUC	NEXT-TASK FAIL	AVERAGE TIME	TIME DEV	PROB. SUC	TIME ESS	REMAINING NON-ESS	SPEC. CODE	JUMP OP1	TASK OP2	JAG.
1			-0	-0.00	2	1	198.460	34.820	.860	2109.480	300.000	-0	-0	-0	-0
2			-0	-0.00	3	2	3.860	1.120	.980	1911.020	300.000	-0	-0	-0	4
3			-0	-0.00	4	3	23.650	1.900	.580	1907.160	300.000	-0	-0	-0	7
4			-0	-0.00	5	4	1.560	.520	.990	1883.510	300.000	-0	-0	-0	7
5			-0	-0.00	6	5	17.800	3.330	.890	1881.950	300.000	-0	-0	-0	1
6			-0	-0.00	7	6	2.330	.650	.990	1864.150	300.000	-0	-0	-0	7
7			-0	-0.00	8	7	8.120	2.220	.990	1861.820	300.000	-0	-0	-0	6
8			-0	-0.00	9	8	1.200	.400	.990	1853.700	300.000	-0	-0	-0	7
9			-0	-0.00	10	9	180.000	60.000	.500	1852.500	300.000	-0	-0	-0	8
10			-0	-0.00	11	10	8.120	2.220	.990	1672.500	300.000	-0	-0	-0	6
11			-0	-0.00	12	11	1.200	.400	.990	1664.380	300.000	-0	-0	-0	7
12			-0	-0.00	13	12	12.960	4.320	.990	1663.180	300.000	-0	-0	-0	-0
13			-0	-0.00	14	13	180.000	.600	.500	1650.220	300.000	-0	-0	-0	8
14			-0	-0.00	15	14	8.120	2.220	.990	1470.220	300.000	-0	-0	-0	6
15			-0	-0.00	16	15	1.200	.400	.990	1462.100	300.000	-0	-0	-0	7
16			-0	-0.00	17	16	55.120	20.080	.990	1460.900	300.000	-0	-0	-0	-0
17			-0	-0.00	18	17	8.120	2.220	.990	1405.780	300.000	-0	-0	-0	6
18			-0	-0.00	58	18	1.200	.400	.990	1397.660	300.000	-0	-0	-0	7
19		N	-0	-0.00	20	19	150.000	50.00	.990	1396.460	300.000	-0	-0	-0	8
20			-0	-0.00	21	20	28.000	5.820	.980	1396.460	150.000	-0	-0	-0	-0
21			-0	-0.00	22	21	2.330	.650	.990	1368.460	150.000	-0	-0	-0	7
22			-0	-0.00	23	22	5.000	1.000	.980	1366.130	150.000	-0	-0	-0	-0
23			-0	-0.00	24	23	1.100	.330	.990	1361.130	150.000	-0	-0	-0	-0
24			-0	-0.00	25	24	193.460	34.820	.880	1360.030	150.000	-0	-0	-0	-0
25			-0	-0.00	26	25	34.790	1.810	.790	1166.570	150.000	-0	-0	-0	-0
26			-0	-0.00	27	26	165.360	34.780	.980	1131.780	150.000	-0	-0	-0	-0
27			-0	-0.00	28	27	16.930	1.520	.890	966.420	150.000	-0	-0	-0	2
28			-0	-0.00	29	28	16.930	1.520	.890	949.490	150.000	-0	-0	-0	2
29			-0	-0.00	30	29	4.660	.920	.980	932.560	150.000	-0	-0	-0	2
30			-0	-0.00	31	30	4.660	.920	.980	927.900	150.000	-0	-0	-0	2
31			-0	-0.00	32	31	8.510	1.120	.970	923.240	150.000	-0	-0	-0	2
32			-0	-0.00	33	32	8.510	1.120	.970	914.730	150.000	-0	-0	-0	2
33			-0	-0.00	34	33	16.930	1.520	.890	906.220	150.000	-0	-0	-0	2
34			-0	-0.00	35	34	16.930	1.520	.890	889.290	150.000	-0	-0	-0	2
35			-0	-0.00	36	35	8.120	2.220	.990	872.360	150.000	-0	-0	-0	6
36			-0	-0.00	37	36	1.200	.400	.990	864.240	150.000	-0	-0	-0	7
37			-0	-0.00	38	37	8.120	2.220	.990	862.040	150.000	-0	-0	-0	6
38			-0	-0.00	39	38	1.200	.400	.990	854.920	150.000	-0	-0	-0	7
39	D		-0	-0.00	40	1	-0.000	-0.000	.950	853.720	150.000	-0	-0	-0	-0
40	D		-0	-0.00	41	19	-0.000	-0.000	.950	853.720	150.000	-0	-0	-0	-0
41			-0	-0.00	42	41	28.000	5.820	.980	853.720	150.000	-0	-0	-0	-0
42			-0	-0.00	43	42	2.330	.650	.990	825.720	150.000	-0	-0	-0	7
43			-0	-0.00	44	43	2.330	.650	.990	823.390	150.000	-0	-0	-0	7
44			-0	-0.00	45	44	2.710	1.060	.970	821.060	150.000	-0	-0	-0	7
45			-0	-0.00	46	45	1.200	.400	.990	818.350	150.000	-0	-0	-0	7
46			-0	-0.00	47	46	165.360	34.780	.890	817.150	150.000	-0	-0	-0	-0
47			-0	-0.00	48	47	5.000	1.000	.980	651.790	150.000	-0	-0	-0	-0
48			-0	-0.00	49	48	17.800	3.330	.890	646.790	150.000	-0	-0	-0	7
49			-0	-0.00	50	49	165.360	34.780	.980	628.990	150.000	-0	-0	-0	-0
50			-0	-0.00	51	50	193.460	36.820	.880	463.630	150.000	-0	-0	-0	-0
51			-0	-0.00	52	51	5.000	1.000	.980	270.170	150.000	-0	-0	-0	-0
52			-0	-0.00	53	52	1.100	.330	.990	265.170	150.000	-0	-0	-0	-0
53			-0	-0.00	54	53	25.630	1.570	.810	264.079	150.000	-0	-0	-0	-0
54			-0	-0.00	55	54	55.120	20.080	.990	238.440	150.000	-0	-0	-0	-0
55			-0	-0.00	56	55	12.860	4.320	.990	183.320	150.000	-0	-0	-0	-0
56			-0	-0.00	57	56	5.000	1.000	.980	170.860	150.000	-0	-0	-0	-0
57			-0	-0.00	58	57	-0.000	4.751	.980	165.180	150.000	-0	-0	-0	-0
58	D		-0	-0.00	59	58	-0.000	-0.000	.800	1.000	150.000	-0	-0	-0	-0
59	D		-0	-0.00	60	59	-0.000	-0.000	.800	0.000	150.000	-0	-0	-0	-0
60	D		-0	-0.00	61	60	-0.000	-0.000	.880	0.000	150.000	-0	-0	-0	-0
61	D		-0	-0.00	62	61	-0.000	-0.000	.950	0.000	150.000	-0	-0	-0	-0
62		N	-0	-0.00	-0	62	150.000	50.000	.990	0.000	150.000	-0	-0	-0	-0

Figure 3-2. Sample Input Data Sheet

- This drawing is not to scale in time, but zero time starts at the left and when the two technicians are at the same point in time. A vertical line shows this synchronization and an encircled number shows the time, in seconds, at that point. It may be desirable to prepare the time line drawing to scale if the drawing is to be used for presentation or other study purposes, but is not required for calculation of T_{ij}^{E} and T_{ij}^{N} values.

- A double horizontal line for a technician indicates that the technician is waiting for another technician due to a specified d_{ij} value.

- The shaded semicircle, between tasks 2 and 3 for technician 2, indicates that technician 1 cannot begin his task 4 until technician 2 completes task 2. There is no waiting required because technician 2 will normally finish task 2 before technician 1 starts task 4.

- The average duration of all waits must now be calculated. They are shown above the double horizontal lines in parentheses. The first (left most) value is the sum of technician 1's tasks 1 and 2 (8.6). The next wait is the length of task 1 for technician 2 (5.0), the third was determined to be the difference between completion of task 5 by technician 1 and completion of task 3 by technician 2 = 25.7 - (13.6 + 2.0 + 4.2) = 5.9.

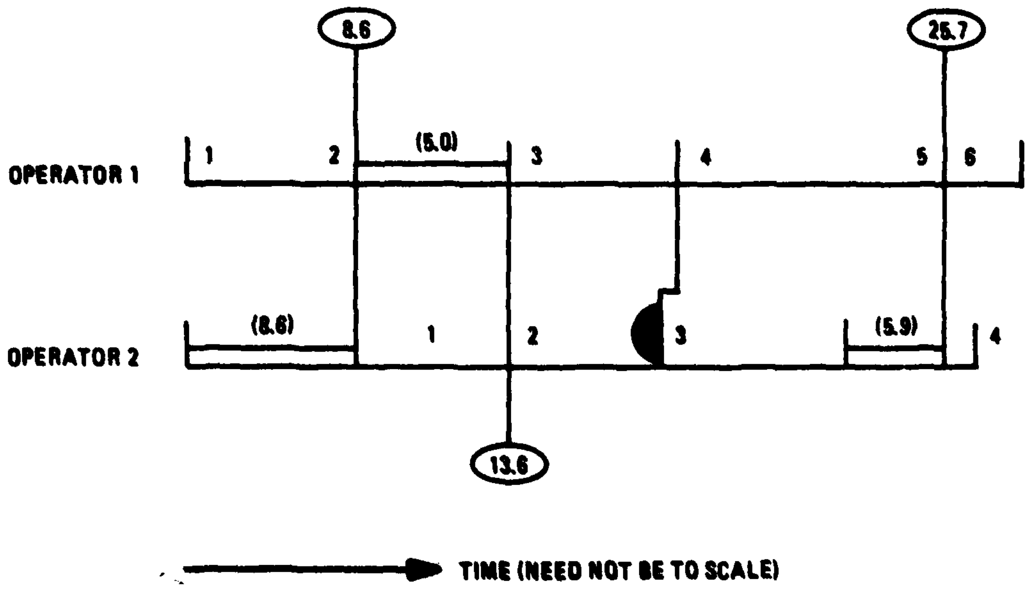

Figure 3-3. Sample Time Line Drawing

Table 3-3. Sample Hypothetical Task

Operator (j)	i	d_{ij}	$\bar{t}_{ij}$	Essential	T^N_{ij}	T^E_{ij}
1	1	0	6.5	Yes	2.1	31.8
	2	0	2.1	Yes	2.1	25.3
	3	1	3.8	Yes	2.1	18.2
	4	2	6.2	Yes	2.1	14.4
	5	2	2.1	No	2.1	8.2
	6	2	8.2	Yes	0	8.2
2	1	2	5.0	Yes	4.2	18.9
	2	2	2.0	Yes	4.2	13.9
	3	2	4.2	No	4.2	11.9
	4	5	6.0	Yes	0	6.0

3.2.3.2 ***Calculation Method.*** The general rule for calculating T^E_{ij} and T^N_{ij} is as follows:

Start at the end of the mission and add $\bar{t}_{ij}$ values successively, taking waiting times and essentiality into account. With no waiting time, the calculation for essential tasks is:

$$T^E_{i+1,j} = T^E_{ij} + \bar{t}_{ij} \qquad (3\text{-}1)$$

For nonessential tasks with no waiting time, the calculation is:

$$T^N_{i+1,j} = T^N_{ij} + \bar{t}_{ij} \qquad (3\text{-}2)$$

Table 3-4 presents a running account of T^E_{ij} and T^N_{ij} calculations for the sample task presented in table 3-3 and figure 3-3.

Checks:	Sum of execution times for operator 1	28.9
	Wait for operator 1	5.0
	Total	33.9
	$T^E_{ij} + T^N_{ij}$ for operator 1	33.9
	Average completion time for operator 1	33.9
	Sum of execution times for operator 2	17.2
	Wait for operator 2	14.5
	Total	31.7
	$T^E_{ij} + T^N_{ij}$ + initial wait for operator 2	31.7
	Average completion time for operator 2	31.7

In the event of a decision (branch), the T^E_{ij} values should be calculated for all tasks following the branch first; then these times are multiplied by the probabilities for the respective branches and the products are added. This yields a single value to which the next earlier $\bar{t}_{ij}$ can be added to determine the T^E_{ij} for the task preceding the branch. T^N_{ij} is treated similary.

Values of T_{ij}^{E} and T_{ij}^{N} are used in the method only for calculating stress. Since these values are cumulative, a calculational error results in T_{ij}^{E} values which are incorrect thereafter. Accordingly, double checks during the process are justified. For long tasks, in which T_{ij}^{E} values for early tasks are large, an error would result in only a small error in stress. For example, if the time allotted were 50 minutes (3000.0 seconds) and the value of T_{ij}^{E} for the first task was 2400.0, the stress would be 1.25 at the beginning of the mission (3000/2400). If, by error, T_{ij}^{E} was calculated to be 2410, the stress would be 1.245, an error of 0.005, resulting in little effect on execution times.

Table 3-4. T_{ij}^{E} and T_{ij}^{N} Calculations for Sample Task

Technician	Task	T_{ij}^{E}	T_{ij}^{N}	Comments
1	6	8.2	0	Last essential subtask for technician 1 – T_{ij}^{E} is the same as $\bar{t}_{ij}$
2	4	6.0	0	Last essential subtask for technician 2 – T_{ij}^{E} is the same as $\bar{t}_{ij}$
1	5	8.2	2.1	Nonessential subtask T_{ij}^{E} unchanged from subtask 6
1	4	14.4	2.1	Essential subtask – $T_{ij}^{E} = 8.2 + 6.2$ – T_{ij}^{N} unchanged
1	3	18.2	2.1	Essential subtask – $T_{ij}^{E} = 14.4 + 3.8$ – T_{ij}^{N} unchanged
2	3	11.9	4.2	Nonessential subtask during an essential waiting period of 5.9 seconds – $T_{ij}^{E} = 6.0 + 5.9$
2	2	13.9	4.2	Essential subtask – $T_{ij}^{E} = 11.9 + 2.0$ – T_{ij}^{N} unchanged
2	1	18.9	4.2	Essential subtask – $T_{ij}^{E} = 13.9 + 5.0$ – T_{ij}^{N} unchanged
1	2	25.3	2.1	Essential subtask including a waiting period – $T_{ij}^{E} = 18.2 + 2.1 + 5.0$ – T_{ij}^{N} unchanged
1	1	31.8	2.1	Essential subtask – $T_{ij}^{E} = 25.3 + 6.5$ – T_{ij}^{N} unchanged

3.2.4 *Punched Card Preparation.* Six types of punched cards are used in the computer simulation. These cards are designated Types 0 through 5, as shown in figure 3-4. Instructions for the preparation of cards 1 through 4 are presented in the following paragraphs.

3.2.4.1 *Information Cards.* The task and parameter inputs are preceded by information inputs that supply data on the general conditions of the run. The information cards are as follows:

- Card Type 1 - General information card provides run instruction codes
- Card Type 2 - Number of Subtasks Card

Card punch instructions for the information cards are presented in table 3-5.

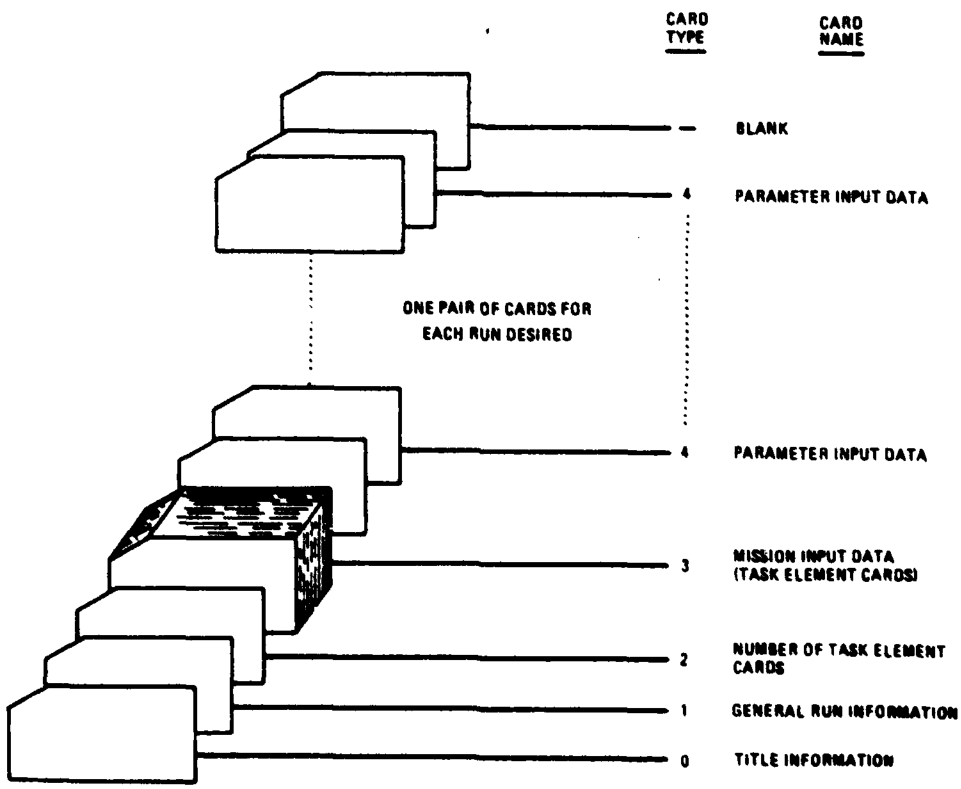

Figure 3-4. Card Deck Layout

Table 3-5. Preparation of Information Cards, Types 1 and 2 (Format I5)

Card Type and Symbolic FORTRAN Name	Card Columns	Contents	Remarks
Card Type 1:			General information card
NUMTRL	1- 5	Run number	Run identifier
NUMRUN	6-10	Number of runs	
NUMIT	11-15	Number of iterations	Per run (Symbol "N")
IND 1	16-20	Random number count	Number of times random number generator subroutine is called before run starts
IND 2	21-25	Type of output for first ICHG iterations (ICHG defined below)	0 = run summary etc.
IND 3	26-30	–	Subtracted from IND 2 after ICHG iterations
IND 4	31-35	Unit of time	value = 1
IND 5	36-40	–	0 = hours 1 = seconds 2 = minutes
ICHG	4-45	–	Number of iterations before changing type of output
Card Type 2:			
NINPC	1-5	Total number of mission input data (subtask) cards included in the run and the sum of the last task numbers for both operators	

3.2.4.2 *Subtask Input Data Card*. Using the input data sheet, prepare a subtask input data card (card Type 3) for each subtask listed. A limit of 300 subtasks for each technician has been established for the simulation model; do not exceed this limit. The content and format of the subtask input card is outlined in table 3-6. Table 3-7 provides an explanation of the data items included on the subtask input data card.

3.2.4.3 *Parameter Input Data Cards.* Prepare one parameter input data card (card Type 4) for each technician.

Four parameters are provided to the model on input cards in the format shown in table 3-6. A pair of cards, one card for each technician, is supplied for each computer run desired. A run is composed of the simulation of N task performances (iterations). The contents in table 3-5 are as follows:

- *Stress threshold* - The stress threshold is considered the technician's "breaking point." The model's simulation is based on the psychological concept that time stress organizes behavior up to a threshold point and disorganizes it beyond that point. Stress is calculated as the ratio of the average time to complete the remaining essential subtasks to the total time remaining to the technician. A value

Table 3-6. Content and Format for Subtask Input Data Cards (Card Type 3)

Symbolic FORTRAN Name	Card Columns	Format	Contents	Symbol	Remarks
J	1	I1	operator number	j	1 or 2
I	3-5	I3	subtask element number	i	1, 2, . . . , 300
J,E,D,C	7	A1	type of subtask element	-	J = Joint; E = Equipment, D = Decision; C = Cyclic
N; Blank	9	A1	essentiality indicator	E_{ij}	N = nonessential; Blank = essential
IPREC(I, J)	10-12	I3	subtask element precedence	d_{ij}	subtask element number of partner
TMBEG(I, J)	13-20	F8.2	time precedence	I_{ij}	earliest time task can start
NXTS(I, J)	21-24	I4	next subtask element success	$(ij)_s$	next subtask element number, if successful
NXTF(I, J)	25-28	I4	next subtask element failure	$(ij)_f$	next subtask element number, if failure
AVGTM(I, J)	29-37	F9.2	average time	$\bar{t}_{ij}$	average subtask element execution time
AVGTMD(I, J)	38-45	F8.2	time deviation	$\bar{\sigma}_{ij}$	average sigma for $\bar{t}_{ij}$
PRBUSC(I, J)	46-50	F5.2	probability of success	$\bar{p}_{ij}$	probability that next subtask element will be $(ij)_s$
TMLE(I, J)	51-59	F9.2	time remaining, essential	T^E_{ij}	sum of time of remaining essential subtask elements
TMLN(I, J)	60-67	F8.2	time remaining, nonessential	T^N_{ij}	sum of time of remaining nonessential subtask elements
ISJT(I, J)	69	I1	special jump subtask element type	–	blank = none; 1 = special type, 1;2 = special type 2 (Team Decision)
NXTJ(I, J)	70-72	I3	next subtask element for j, special	–	applied to j, special jump subtask element
NXTJP(I, J)	73-75	I3	next subtask element for j', special	–	applies to partner, special jump subtask element
JAG(I, J)	76	I1	job activity group	–	1 = Electro-cognition; 2 = Electro-repair 3 = Instruction; 4 = Electro-safety 5 = Personnel Relationships 6 = Electronic Circuit Analysis 7 = Equipment Operation 8 = Using Reference Material 9 = Equipment Inspection

of stress greater than unity but less than the threshold will increase the technician's speed and success probability. At the threshold, the effect of stress is reversed, simulating disorganization and confusion of the technician.

- *F factor* - The F factor for each technician is an individuality indicator representing technician speed or proficiency. An average technician is given an F factor of unity; faster and more proficient technicians have lower values; slower and less proficient technicians have higher F values.

- *Time available* - The total time available to complete the task is a time limit. This value is employed as the interim of task success.

- *Period* - The period refers to the period of time applicable to cyclic subtasks. A cyclic subtask is initiated only at a time that is a multiple of the period, P. The simulated technician waits, if necessary, until such time occurs.

Table 3-7. Preparation of Subtask Input Data Cards

Data Item	Description
Operation number	Operator designation (1 or 2)
Subtask element number	Sequential task number (1 through 300)
Type of subtask element	Type J: Joint subtask-Performed simultaneously by two technicians Type E: Equipment subtask-Causes a delay due to a factor other than technician performance Type D: Decision subtask-Allows for looping, skipping, or branching in the performance sequence i.e.: the next subtask is selected according to the results of the task being performed. Type C: Cyclic subtask-A subtask that cannot be started until the next cycle time in a series of equal time periods.
Essentiality indicator	Identifies optional items
Subtask element precedence	Identifies the subtask element that must be completed by the other member of the team before this subtask can be started
Time precedence	Indicates waiting time from the start of the malfunction correction process before this subtask can be started

Table 3-7. Preparation of Subtask Input Data Cards (Continued)

Data Item	Description
Next subtask element success	Indicates the next subtask to be started if this subtask is successfully completed
Next subtask element failure	Indicates the next subtask to be started if this subtask is failed
Average time	Average execution time for this subtask
Time deviation	Average standard deviation of subtask execution time
Probability of success	From task analytic data; use extent data banks
Time remaining, essential	Sum of time for remaining essential subtasks—calculated after other inputs are prepared
Time remaining nonessential	Sum of time for remaining nonessential subtasks—calculated after inputs are prepared
Special jump subtask element type	The special jump subtask type 1 enables both technicians to jump to an individually specified subtask if one of the technicians ignores a given subtask. If a subtask, so identified, is ignored, technician j will go to NXTJ (I, J) for his next subtask; his partner, technician j, will go to NXTJP (I, J). Special jump subtask type 2 provides a team decision capability to the model. If a subtask, so identified, is a success, technician j will go to NXTS (I, T) for his next subtask. If the subtask is failed, technician i goes to NXTJ (I. J) and his partner, technician j', goes to NXTP (I, J). Thus, one technician can make a decision which will determine the future sequence of subtasks for both technicians
Next subtask element for j, special	Indicates next subtask if this subtask is being performed as a special jump subtask
Next subtask element for j' special	Indicates next subtask for the other technician involved in a special jump subtask
Job activity group	Identifies the task associated with this subtask

Table 3-8. Content and Format of Parameter Input Data Cards (Card Type 4)

Symbolic FORTRAN Name	Card Columns	Format	Content	Symbol	Remarks
J	1	I1	Technician number	j	1 or 2
STRM (J)	2-11	F10.0	Stress threshold	M_j	$M_j > 1.9 < 2.8$
SPEED (J)	12-21	F10.0	F factor	F_j	$F_j < 1$: faster $F_j > 1$: slower
TMAVA (J)	22-31	F10.0	Time available	T_j	Time remaining
PRD (J)	32-41	F10.0	Period	P_j	Period for cyclic tasks 9 (seconds)
JOT (J)	43	I1	Job technician type	-	0. None of the following 1. Electrician's mate 2. Electronic technician 3. Fire control technician 4. Interior communications electrician 5. Radarman 6. Radioman 7. Sonar technician 8. Torpedoman's mate

3.3 Results of Computer Simulation

The computer simulation model produces a variety of data which is typically recorded on magnetic tape for subsequent printout on a high speed line printer. The categories of results available are summarized in table 3-9. The probability of successful completion of mission tasks can be obtained by analyzing the computer printouts.

3.3.1 *Iteration Summary.* Figure 3-5 shows a portion of the iteration summaries for the sample task that was presented in table 3-1. The iteration summaries contain the following data for each simulated technician:

- The input stress threshold
- The input speed (proficiency)
- The total input available time

- The difference between the available time and the actual time used
- The time spent waiting for the other technician (two technician case only)
- Subtask on which the peak (maximum) stress occurred and the peak stress level reached
- The stress level of each technician at the end of the simulation
- Team cohesiveness at the end of the simulation
- Time spent waiting for a given equipment cycle

Table 3-9. Computer Simulation Results

Title	Frequency	Remarks
Detail listing	Every subtask	Optional, 1 line per subtask
Iteration summary	At end of each iteration	Optional, 7 lines per iteration iteration
Run summary	At end of run	9 lines plus 8 frequency distributions for each technician

3.3.1.1 *Malfunction Correction Time Prediction*. The iteration summaries provide the data needed to predict the time it will take the technicians to correct a given malfunction. The procedure for using the iteration summaries to predict total malfunction correction time is shown in figure 3-6 and described as follows:

- Prepare a frequency distribution of the total time used data for each iteration
- Convert the frequency data to cumulative proportions (stated in percent)
- Plot the cumulative percentages against time and draw a line of best fit on the plot
- Draw a horizontal line from the line of best fit to the 50 percent point on the ordinate of the graph.

```
OPR  THRES  SPEED   - - - - -    T I M E S    - - - - -  PEAK STRESS      FINAL    LAST    CYCLIC
NO   HOLD                AVAIL     USED     DIFF    WAIT   TASK    VALUE    STRESS   COMES    WAIT
 1    2.30   1.00      1399.00   1289.48 -109.5     0.0      1      1.00      1.00    0.00    0.00
 2    2.30    .90      1399.00        .75-1398.2    0.0      1      1.00      1.00    0.00    0.00

SUMMARY OUTPUT OF ITERATION     2        RUN     1        TRIAL     4
         OVER RUN        TOTAL TIME USED     1415.24

OPR  THRES  SPEED   - - - - -    T I M E S    - - - - -  PEAK STRESS      FINAL    LAST    CYCLIC
NO   HOLD                AVAIL     USED     DIFF    WAIT   TASK    VALUE    STRESS   COMES    WAIT
 1    2.30   1.00      1399.00   1415.24   16.2     0.0     43      2.30      2.30     .30    0.00
 2    2.30    .90      1399.00        .75-1398.2    0.0      1      1.00      2.30    0.00    0.00

SUMMARY OUTPUT OF ITERATION     3        RUN     1        TRIAL     4
         UNDER RUN       TOTAL TIME USED     1345.24

OPR  THRES  SPEED   - - - - -    T I M E S    - - - - -  PEAK STRESS      FINAL    LAST    CYCLIC
NO   HOLD                AVAIL     USED     DIFF    WAIT   TASK    VALUE    STRESS   COMES    WAIT
 1    2.30   1.00      1399.00   1345.24  -53.8     0.0      1      1.00      1.00    0.00    0.00
 2    2.30    .90      1399.00        .75-1398.2    0.0      1      1.00      1.00    0.00    0.00

SUMMARY OUTPUT OF ITERATION     4        RUN     1        TRIAL     4
         UNDER RUN       TOTAL TIME USED     1277.09

OPR  THRES  SPEED   - - - - -    T I M E S    - - - - -  PEAK STRESS      FINAL    LAST    CYCLIC
NO   HOLD                AVAIL     USED     DIFF    WAIT   TASK    VALUE    STRESS   COMES    WAIT
 1    2.30   1.00      1399.00   1277.09 -121.9     0.0      1      1.00      1.00    0.00    0.00
 2    2.30    .90      1399.00        .75-1398.2    0.0      1      1.00      1.00    0.00    0.00

SUMMARY OUTPUT OF ITERATION     5        RUN     1        TRIAL     4
         OVER RUN        TOTAL TIME USED     2789.58

OPR  THRES  SPEED   - - - - -    T I M E S    - - - - -  PEAK STRESS      FINAL    LAST    CYCLIC
NO   HOLD                AVAIL     USED     DIFF    WAIT   TASK    VALUE    STRESS   COMES    WAIT
 1    2.30   1.00      1399.00   2789.58 1390.6     0.0      1      5.00      2.30     .30    0.00
 2    2.30    .90      1399.00        .75-1398.2    0.0      1      1.00      2.30    0.00    0.00

SUMMARY OUTPUT OF ITERATION     6        RUN     1        TRIAL     4
         OVER RUN        TOTAL TIME USED     3899.99

OPR  THRES  SPEED   - - - - -    T I M E S    - - - - -  PEAK STRESS      FINAL    LAST    CYCLIC
NO   HOLD                AVAIL     USED     DIFF    WAIT   TASK    VALUE    STRESS   COMES    WAIT
 1    2.30   1.00      1399.00   3899.99 2501.0     0.0      1      5.00      2.30     .30    0.00
 2    2.30    .90      1399.00        .75-1398.2    0.0      1      1.00      2.30    0.00    0.00

SUMMARY OUTPUT OF ITERATION     7        RUN     1        TRIAL     4
         UNDER RUN       TOTAL TIME USED     1336.55

OPR  THRES  SPEED   - - - - -    T I M E S    - - - - -  PEAK STRESS      FINAL    LAST    CYCLIC
NO   HOLD                AVAIL     USED     DIFF    WAIT   TASK    VALUE    STRESS   COMES    WAIT
 1    2.30   1.00      1399.00   1336.55  -62.4     0.0      1      1.00      1.00    0.00    0.00
 2    2.30    .90      1399.00        .75-1398.2    0.0      1      1.00      1.00    0.00    0.00

SUMMARY OUTPUT OF ITERATION     8        RUN     1        TRIAL     4
         OVER RUN        TOTAL TIME USED     2620.25
```

Figure 3-5. Sample of Iteration Summaries

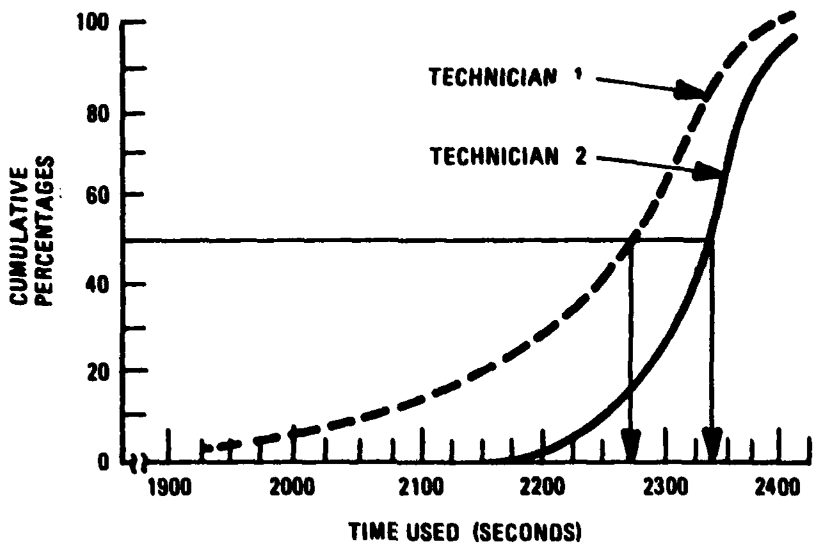

Figure 3-6. Predicted Malfunction Correction Time

The plot shown in figure 3-6 shows separate data for technicians 1 and 2. The data shows that technician 1 is a "fast" (F = 0.9) technician, and technician 2 is a "slow" (F = 1.1) technician. The predictions obtained from figure 3-6 are:

- Fifty percent of the malfunction corrections performed by technician 1 will be performed in 2280 seconds or less.
- Fifty percent of the malfunctions performed by technician 2 will be performed in 2330 seconds or less.
- The range of malfunction correction times for technician 1 will be from 1925 to 2425 seconds.
- The range of malfunction correction times for technician 2 will be from 2145 to 2425 seconds.

3.3.2 *Run Summary.* Figure 3-7 shows a run summary for the sample task. The run summary contains the following data:

- Run number (1)
- Total number of iterations performed (100)
- Number of successful iterations (41)
- Percent successful iterations (41.0)

- Time available, T_j (2409.00)
- The following data are listed for each operator or technician (the results of operator 1 are presented in this case since the malfunction correction is a uni-technician function):
  - Operator number (1)
  - Stress threshold, M_j (2.30)
  - Speed factor, F_j (1.00)
  - Time available, T_j (2409.00)
  - Average time used over N iterations (3565.33)
  - Average time overrun, i.e., time used-time available (1156.33)
  - Average waiting time (0.00)
  - Average peak stress (2.88)
  - Average final stress (1.77)
  - Average cyclic waiting time (0.00)
- The following frequency distributions are displayed and values presented for each subtask and for each operator/technician.
  - Subtask number
  - A count for the number of times that subtask was the last one completed before finishing the iteration or running out of time. The last subtask, 62, was the last subtask completed 41 times.
  - A count of the number of times a subtask was failed
  - A count of the number of times a subtask was ignored
  - The time spent in repeating subtasks that were failed
  - A count of the number of times the peak stress occurred on each subtask
  - The average time, from the beginning of the malfunction correction, that the subtask was completed
  - The average stress prior to beginning each subtask
  - Average cohesiveness value on each subtask

The data provided by the run summary may be employed as a basis for gaining insight into areas for redesign so as to decrease maintenance time. For example, subtasks involving large times may be considered for redesign or for training emphasis. Similarly, subtask yielding high failure frequencies may be considered for special treatment. If the malfunction correction method is revised, the revision may be analyzed through the computer simulation method to indicate the extent of the reduction in estimated malfunction correction time brought about by the revision.

3.4 Summary of Use of Computer Simulation Technique

The steps involved in applying the computer simulation method for estimating time to repair for a given electronic system are:

- For the system under consideration select a representative and adequate sample of the malfunction correction situations
- For each malfunction correction in the sample, prepare a sequential list of the subtasks involved in malfunction correction
- Prepare the input data for each malfunction
- Run each simulation for a minimum of 100 iterations
- Graphically summarize the data by malfunction and across malfunctions
- The across malfunction data summary yields the estimated time to repair for the system

3.5 Simulation Program Data

Program data for the digital simulation one and two technician model are presented in the appendixes. These data are identified as follows:

- Defintions of the variables in the computer simulation program are presented in appendix A.
- The program listing for the simulation program is presented in appendix B.
- The program flow charts are presented in appendix C.

SUMMARY OUTPUT OF RUN 1
NUMBER OF ITERATIONS 100
NUMBER OF SUCCESSES 41
WTD CRNT SUCCESSES 41.0 FOR TIME DURATION 2404.0

OPR NO.	THRES -2LO	SPEED	AVERAGE TIMES AVAIL	USED	DIFF	WAIT	PEAK STRESS	FINAL STRESS	CYCLIC WAIT
1	2.30	1.00	2400.00	3546.33	-1146.33	0.00	7.00	1.77	0.00
2	2.30	.00	2400.00	.75	2400.25	0.00	1.00	1.77	0.00

FREQUENCY DATA

TASK NO	LAST TASK COMPLETED OP 1	OP 2	TASK FAILED OP 1	OP 2	TASK IGNORED OP 1	NE	OP 2	NE	FAILURE TIMES OP 1	OP 2	PEAK STRESS OP 1	OP 2	AVG TIME CMPLTD OP 1	OP 2	AVG START TOT STRESS OP 1	OP 2	AVG COHESIVE OP 1	OP 2
1	1	100	36	0	0		0		8317.16	0.00	52	82	1796.95	.75	1.72	1.00	.17	0.00
2	0	0	7	0	0		0		25.57	0.00	5	10	1778.11	0.00	1.54	0.00	.13	0.00
3	0	0	14	0	0		0		250.34	0.00	0	0	1752.14	0.00	1.53	0.00	.12	0.00
4	0	0	0	0	0		0		0.00	0.00	0	0	1753.57	0.00	1.53	0.00	.12	0.00
5	0	0	23	0	0		0		391.08	0.00	1	0	1777.27	0.00	1.51	0.00	.12	0.00
6	0	0	8	0	0		0		0.00	0.00	1	0	1774.51	0.00	1.53	0.00	.12	0.00
7	0	0	5	0	0		0		32.55	0.00	0	0	1787.39	0.00	1.57	0.00	.12	0.00
8	5	0	0	0	0		0		0.00	0.00	0	0	1783.44	0.00	1.54	0.00	.12	0.00
9	0	0	7	0	0		0		1247.33	0.00	1	0	1467.34	0.00	1.52	0.00	.12	0.00
10	0	0	4	0	0		0		37.99	0.00	2	0	1474.03	0.00	1.49	0.00	.11	0.00
11	0	0	0	0	0		0		0.00	0.00	0	0	1478.88	0.00	1.49	0.00	.11	0.00
12	2	0	1	0	0		0		16.37	0.00	0	0	1488.30	0.00	1.49	0.00	.11	0.00
13	0	0	10	0	0		0		1710.99	0.00	0	0	1464.61	0.00	1.49	0.00	.11	0.00
14	0	0	4	0	0		0		25.27	0.00	1	0	1472.05	0.00	1.49	0.00	.11	0.00
15	1	0	0	0	0		0		0.00	0.00	0	0	1473.77	0.00	1.47	0.00	.11	0.00
16	0	0	2	0	0		0		82.08	0.00	0	0	1774.09	0.00	1.47	0.00	.11	0.00
17	0	0	4	0	0		0		20.47	0.00	0	0	1731.57	0.00	1.46	0.00	.11	0.00
18	0	0	0	0	0		0		0.00	0.00	0	0	1732.70	0.00	1.46	0.00	.11	0.00
19	1	0	0	0	129	N	0		0.00	0.00	2	0	1912.74	0.00	1.50	0.00	0.00	0.00
20	0	0	5	0	0		0		144.71	0.00	2	0	1938.43	0.00	1.61	0.00	.14	0.00
21	0	0	0	0	0		0		0.00	0.00	1	0	1940.44	0.00	1.57	0.00	.13	0.00
22	0	0	4	0	0		0		15.77	0.00	0	0	1945.39	0.00	1.56	0.00	.13	0.00
23	2	0	1	0	0		0		1.07	0.00	0	0	1946.47	0.00	1.57	0.00	.13	0.00
24	1	0	21	0	0		0		3079.00	0.00	2	0	2153.72	0.00	1.59	0.00	.14	0.00
25	1	0	25	0	0		0		957.36	0.00	2	0	2191.27	0.00	1.58	0.00	.14	0.00
26	0	0	10	0	0		0		1507.04	0.00	0	0	2352.04	0.00	1.55	0.00	.13	0.00
27	0	0	0	0	0		0		0.00	0.00	1	0	2367.74	0.00	1.55	0.00	.13	0.00
28	0	0	0	0	0		0		0.00	0.00	0	0	2383.64	0.00	1.55	0.00	.13	0.00
29	0	0	0	0	0		0		0.00	0.00	0	0	2387.00	0.00	1.55	0.00	.13	0.00
30	0	0	0	0	0		0		0.00	0.00	0	0	2392.77	0.00	1.55	0.00	.13	0.00
31	0	0	1	0	0		0		9.70	0.00	0	0	2400.19	0.00	1.54	0.00	.13	0.00
32	0	0	1	0	0		0		6.72	0.00	0	0	2408.22	0.00	1.55	0.00	.13	0.00
33	1	0	3	0	0		0		53.75	0.00	0	0	2424.75	0.00	1.55	0.00	.13	0.00
34	0	0	0	0	0		0		0.00	0.00	0	0	2440.34	0.00	1.55	0.00	.13	0.00
35	0	0	3	0	0		0		24.17	0.00	0	0	2447.77	0.00	1.54	0.00	.13	0.00
36	0	0	0	0	0		0		0.00	0.00	0	0	2448.81	0.00	1.53	0.00	.12	0.00
37	0	0	0	0	0		0		0.00	0.00	0	0	2454.44	0.00	1.53	0.00	.12	0.00
38	0	0	0	0	0		0		0.00	0.00	0	0	2457.90	0.00	1.53	0.00	.12	0.00
39	0	0	0	0	0		0		0.00	0.00	0	0	2500.38	0.00	1.53	0.00	0.00	0.00
40	1	0	0	0	0		0		0.00	0.00	0	0	2481.97	0.00	1.55	0.00	0.00	0.00
41	0	0	3	0	0		0		71.04	0.00	2	0	2511.34	0.00	1.63	0.00	.15	0.00
42	0	0	0	0	0		0		0.00	0.00	0	0	2513.53	0.00	1.61	0.00	.14	0.00
43	0	0	0	0	0		0		0.00	0.00	0	0	2514.71	0.00	1.61	0.00	.14	0.00
44	0	0	1	0	0		0		7.54	0.00	0	0	2518.11	0.00	1.61	0.00	.14	0.00
45	3	0	0	0	0		0		0.00	0.00	0	0	2519.51	0.00	1.61	0.00	.14	0.00
46	0	0	13	0	0		0		2210.03	0.00	4	0	2400.43	0.00	1.63	0.00	.15	0.00
47	0	0	4	0	0		0		17.09	0.00	0	0	2495.31	0.00	1.56	0.00	.13	0.00
48	1	0	1	0	0		0		16.11	0.00	0	0	2712.40	0.00	1.56	0.00	.13	0.00
49	1	0	2	0	0		0		317.29	0.00	1	0	2844.05	0.00	1.59	0.00	.14	0.00
50	0	0	13	0	0		0		2310.99	0.00	1	0	3064.85	0.00	1.56	0.00	.13	0.00
51	0	0	3	0	0		0		12.95	0.00	0	0	3060.45	0.00	1.55	0.00	.13	0.00
52	0	0	2	0	0		0		2.74	0.00	0	0	3070.78	0.00	1.55	0.00	.13	0.00
53	0	0	25	0	0		0		605.00	0.00	1	0	3101.47	0.00	1.55	0.00	.13	0.00
54	0	0	0	0	0		0		4.00	0.00	0	0	3153.41	0.00	1.55	0.00	.13	0.00
55	0	0	3	0	0		0		45.31	0.00	2	0	3166.19	0.00	1.56	0.00	.13	0.00
56	17	0	1	0	0		0		3.19	0.00	1	0	3170.04	0.00	1.56	0.00	.13	0.00
57	0	0	17	0	0		0		2200.34	0.00	0	0	3351.05	0.00	1.67	0.00	.16	0.00
58	0	0	0	0	0		0		0.00	0.00	0	0	1817.77	0.00	1.44	0.00	0.00	0.00
59	0	0	0	0	0		0		0.00	0.00	0	0	3448.74	0.00	1.68	0.00	0.00	0.00
60	0	0	0	0	0		0		0.00	0.00	0	0	3409.40	0.00	1.72	0.00	0.00	0.00
61	3	0	0	0	0		0		0.00	0.00	0	0	3534.79	0.00	1.73	0.00	0.00	0.00
62	41	0	0	0	82	N	0		0.00	0.00	0	0	3564.17	0.00	1.72	0.00	0.00	0.00
		TOTAL	283	0	211		0		26057.40	0.00 TOTAL								
	AVERAGE	[illegible]	[illegible]	0.0	2.1		9.0		260.97	0.00 AVERAGE								

Figure 3-7. Run Summary

4.0 INTERMEDIATE SIMULATION MODEL (ISM)

4.1 Introduction

The ISM, also developed at Applied Psychological Services, provides digital simulation of task performance involving 4 to 20 performers and permits the calculation of Human Reliability (HR), Equipment Reliability (ER) and System Reliability (SR) factors, Human Availability (HA), Equipment Availability (EA), System Availability (SA), Human Mean Time to Repair (HMTTR), Equipment Mean Time to Repair (EMTR), and System Mean Time to Repair (SMTTR).

The ISM predicts the time required to complete the simulated task and is capable of predicting the effect of changes in a given variable on HR, ER, or SR. Using inputs for a specific equipment or system, the ISM provides answers to such questions as:

- What is its ER?
- What is its HR?
- Which components of ER contribute most to unreliability?
- Which components of HR contribute most to unreliability?
- What changes in equipment will lead to an increase in ER?
- What personnel changes will increase HR?
- What behavioral variables contribute most to HR?
- What part does ER and HR, respectively, contribute to SR?
- What system design changes will best contribute to an increase in reliability?
- How does crew proficiency affect HR? SR?
- What are the effects of such items as motion sickness, fatigue, morale, level of aspiration, etc., on HR? on SR?

4.1.1 Advantages of the ISM. The advantages of the ISM over the smaller (1 to 2 technician) model are listed in tables 4-1 through 4-4.

Table 4-1. Personnel Parameters

Characteristic	Small Model	Intermediate Model (ISM)
Quantity	1 or 2 men	3-20 men groups group leader
Categories/ type		primary/secondary specialties 10 personnel specialties and cross training command echelon

Table 4-1. Personnel Parameters (Continued)

Characteristic	Small Model	Intermediate Model (ISM)
Goals	goal aspiration	aspiration leaders expectation performance adequacy
Physical Attributes		physical workload motion sickness hazard (safety index) sleep physical incapability (sickness) physical workload
Performance Attributes	stress and stress thresholds cohesiveness individuality (speed) factor	competence fatigue pace stress and stress threshold mental load unmanned station hours

Table 4-2. Mission Parameters

Characteristic	Small Model	Intermediate Model (ISM)
Composition	1-300 tasks	200 events per day of 30 types
Duration	minutes-hours mission time limit	hours to 30 days shifts
Environment		sea state
Elements (tasks)	essentiality types (joint, equipment, decision, cyclic) precedence (task and time) execution time success/failure determination waiting, idling success probability time remaining	essentiality types (scheduled, emergency, repair) precedence (task and time) performance time fixed and variable event times mixed and variable event times touch up or repeat completion time limit

Table 4-3. Equipment Parameters

Characteristic	Small Model	Intermediate Model
Quantity		30 types
Capability	equipment tasks	failure and generation of repairs operator initiated failures
Performance/ Status		failure rates up time down time performance level consumables levels

Table 4-4. Output Measurements

Characteristic	Small Model	Intermediate Model
Mission Effectiveness	mission success probability performance repetitions peak stress tasks mission duration	system reliability level system performance level equipment performance efficiency system global effectiveness level consumables balances equipment and human MTBF & MTTR
Time Utilization	tasks failed, ignored average time used waiting time average time overrun peak and average stress number of tasks and last task completed	success, idle, sleep, repair no. of events, success, fail, ignore, primary, secondary
Personnel	goal aspiration performance average cohesiveness	performance adequacy physical and mental load health and safety indices performance
Report Frequency	task, mission, iteration, and run summary	event, day, mission iteration, and run summary

4.1.2 Flow Logic Sequencing. Figure 4-1 provides a summary of the flow logic sequencing for the model. The detailed logical flow diagram of the model is presented in appendix C. Figure 4-1 is compatible with the detailed flow chart presented in appendix C. Key points in the model are identified by circled lowercase letters in figure 4-1 and in the flow diagram in appendix C; the point identified by a particular letter in figure 4-1 is identical to the point identified by the same letter in appendix C.

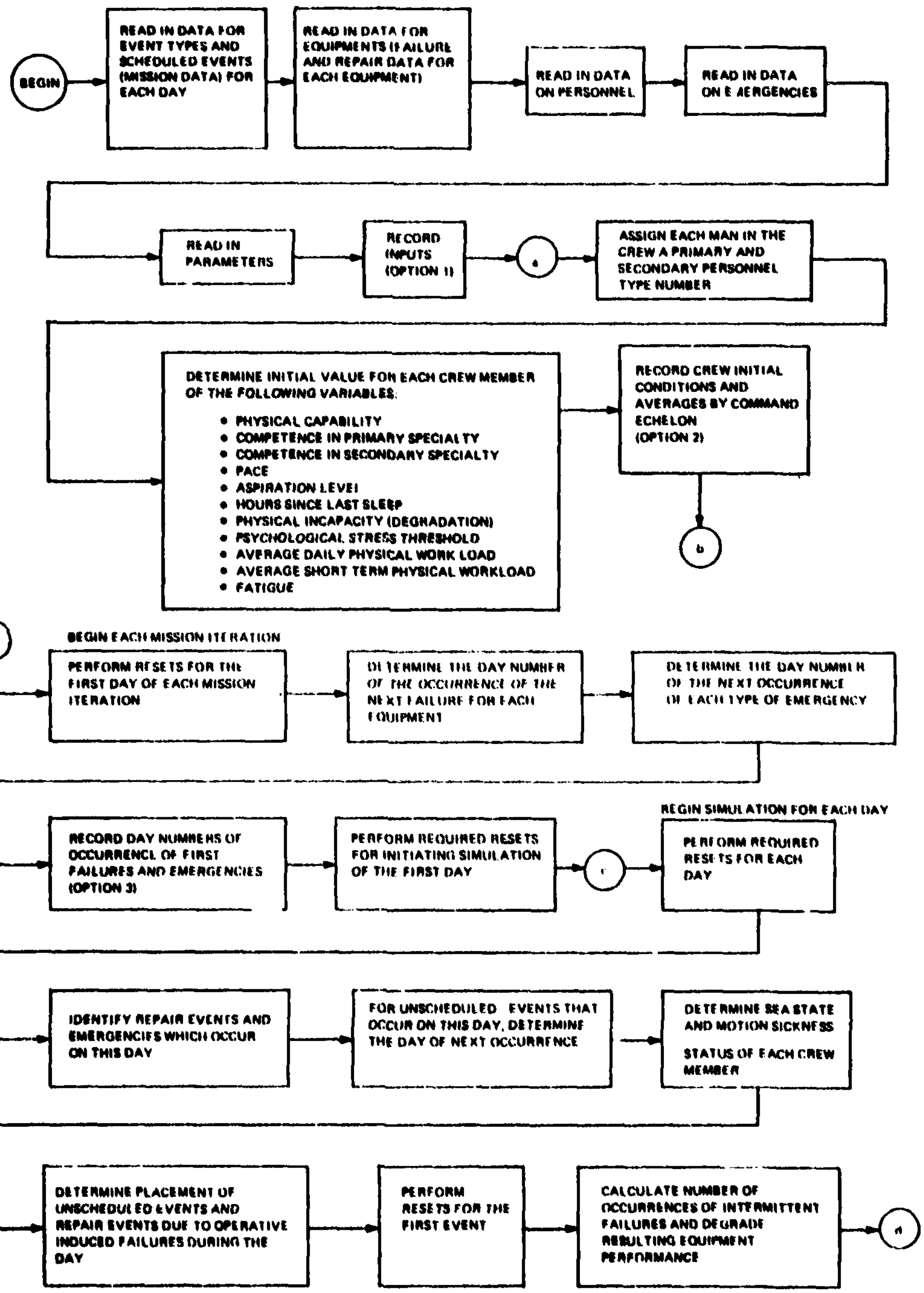

Figure 4-1 (Sheet 1). General Flow Logic Diagram of Model

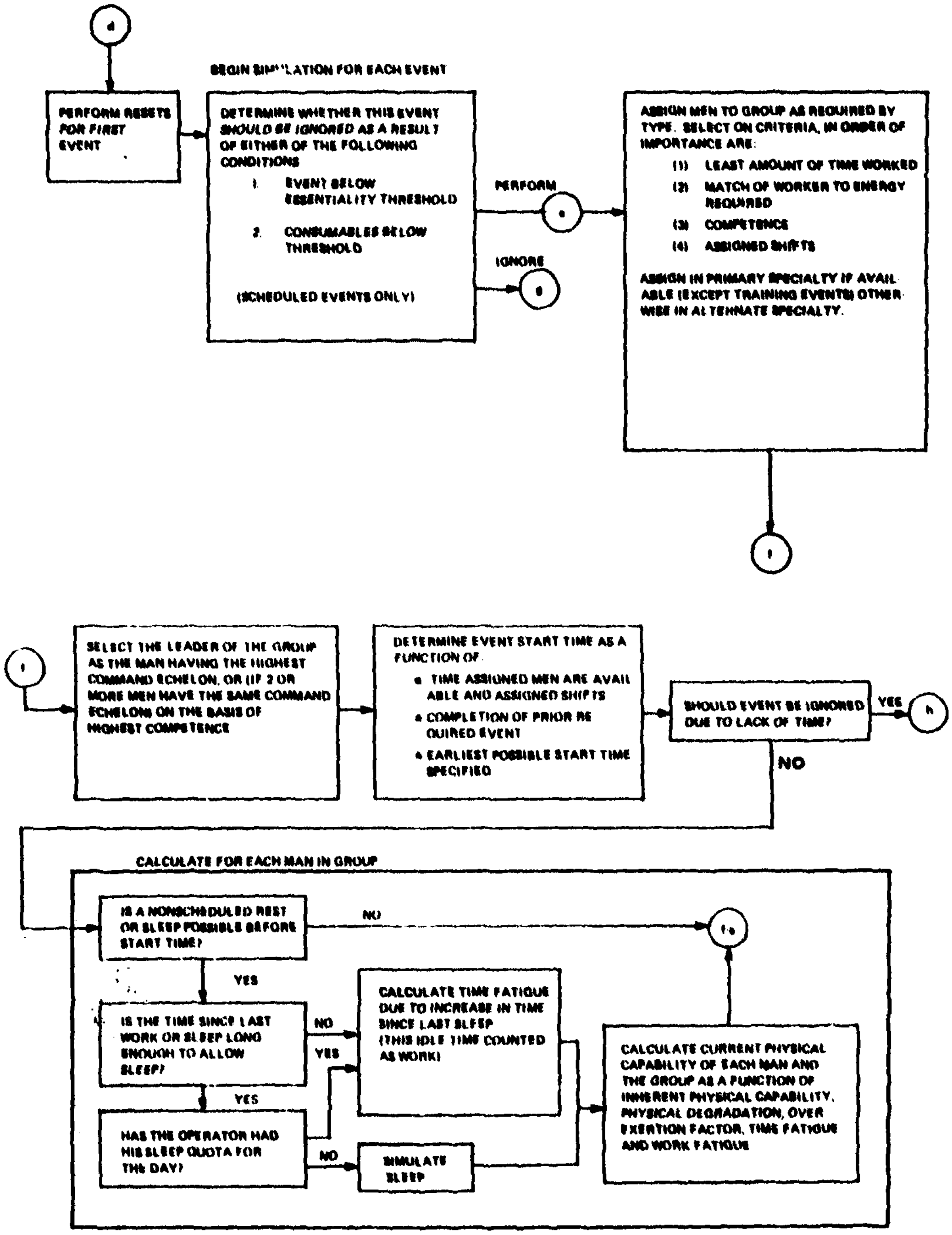

Figure 4-1 (Sheet 2). General Flow Logic Diagram of Model

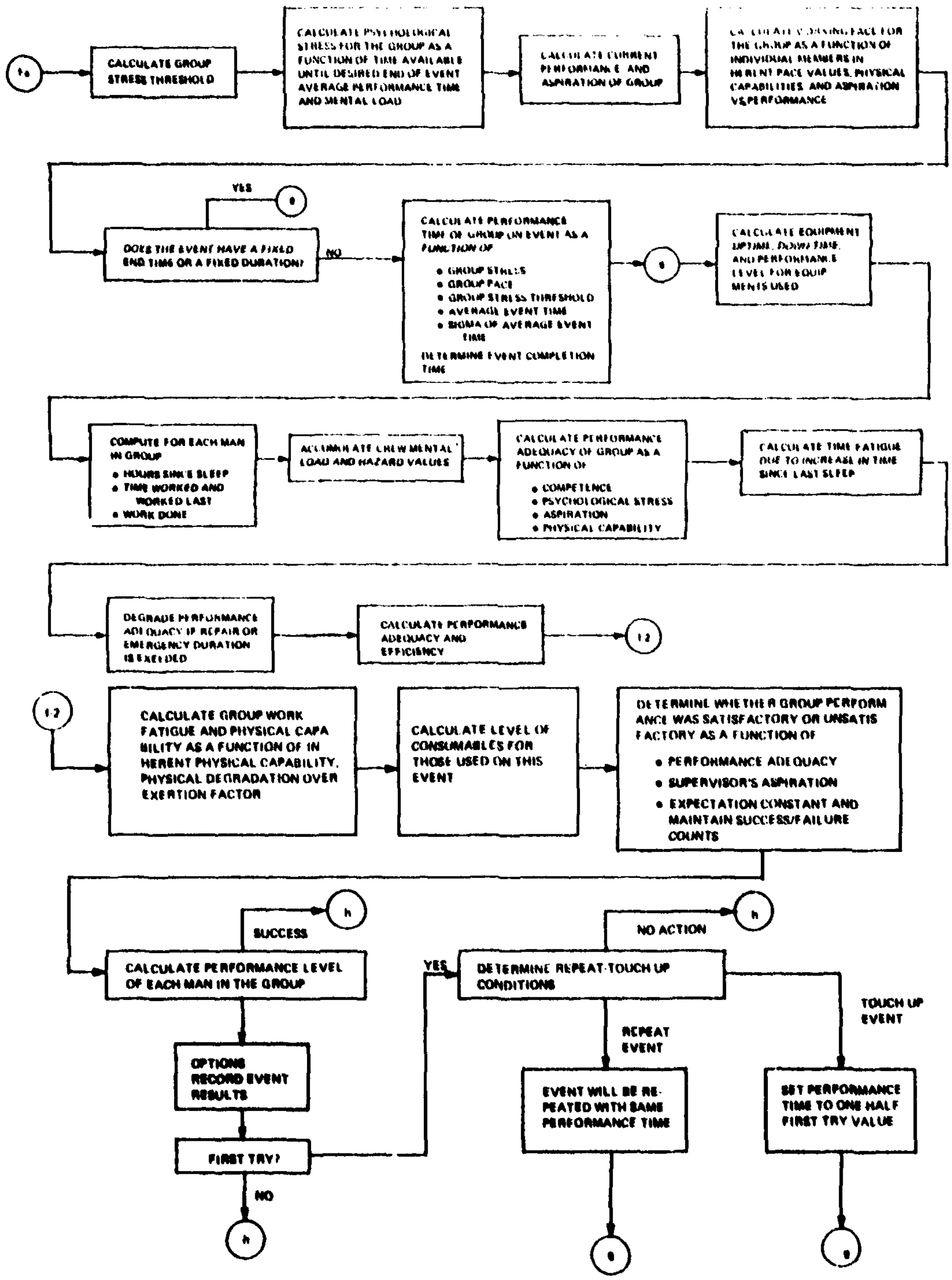

Figure 4-1 (Sheet 3). General Flow Logic Diagram of Model

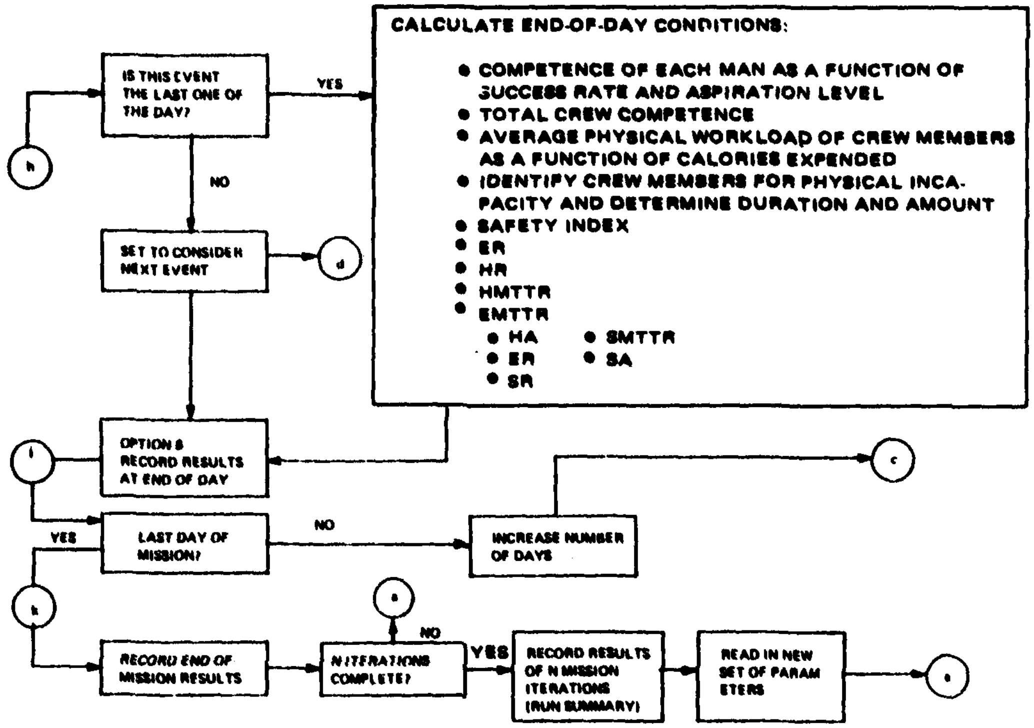

Figure 4-1 (Sheet 4). General Flow Logic Diagram of Model

4.2 Input Data

Each item of input data including other working variables in the input subroutine used in the model is defined in table 4-5. Table 4-5 gives the range and the average values for each input data item where applicable. The "Remarks" column of table 4-5 provides other pertinent data such as the unit of measure for quantitative items.

Table 4-5. Input Data

FORTRAN	Description	Range	Average	Remarks
AASP	Average aspiration	.5-1.0	.9	
ACP	Average crew pace	5-1.5	1.0	
ADUR	Average duration of scheduled event	.001-24	–	Time in hours and hundreds
APST	Average psychological stress threshold	2.0-2.6	2.3	
ART	Average repair time	0-24	–	Time in hours
ASD	Average standard deviation of repair	0-999	–	
ASDE	Average standard deviation of emergency	0-24		Time in hours
BE	Effectivity of stress	.5-1.0	.9	

Table 4-5. Input Data (Continued)

FORTRAN	Description	Range	Average	Remarks
CALRY	Number of calories required by average crewman per day	2000-3500	2750	
CN	Catnap length	.1 to 2	.3	
DTE	Duration time of emergencies	0-24		Time in hours
DTR	Duration time of repairs	0-24		Time in hours
EDCV	Data change value	0-10	–	
EMREVT	Emergency event data set			
EQREVT	Repair event data set			
ICLASS	Class	1-20		
IDES	Description array			
IDS	Number of duty shifts			
IEC	Expected energy consumption	0-1000	250	Calories per hour
IECE	Expected energy consumption for emergency	100-1000	250	Calories per hour
IEDC	Data change variable	0-10	–	
IEFN	Family number	1-20		
IESS	Essentiality	10-100		
IESS	Emergency essentiality	0-100		
IET	Essentiality threshold	0-99	70	
IETYP	Event type number	0-20		
IFOI	Event number in family	0-200		
IH	Event hazard class	1-9		
IHE	Event hazard class (emergency)	1-5		
IND	Printout option indicator array	0 or 1	1	
INT	Event code	1 or 2		
IPE	Prerequisite event	0-200		
IQR	Equipment list	1-10		
IRC	Consumable rate of expenditure units/hours)	0.9999	–	
IRC1	Consumable rate of expenditure (units)	0-9999	–	
IRCE1	Consumable rate of expenditure (units)–emergencies	0-9999		
IRE	Number of repair events	0-200		
K1	Physical capacitation fraction	0-1.0	.75	
K7	Derating constant	.5-1.0	.9	
KE	Event end type	1 or 2		
KON	Initial level of consumables (units/hours)			
KON1	Initial level of consumables (units)	0-9999		
KONT	Threshold consumables (units/hours)	0-9999		
KONT1	Threshold consumables (units)	0-9999		
LODM	Mental load	1-9		
LODME	Mental load for emergency	1-9		
MAXSL	Maximum sleep	4-12	8	
MEN	Crew composition array	0-10		

Table 4-5. Input Data (Continued)

FORTRAN	Description	Range	Average	Remarks
MPI	Average number of man days per incidence of physical incapacitation	0-120	30	
N	Number of iterations	1-999	20	
ND	Number of days	1-100		
NDBE	Number of days between emergencies	0-1000		
NDMAX	Maximum number of days	1-30	5	
NDS	Duty shift			
NIF	Number of family	1-10		
NIQR	Equipment used array	1-10		
NOSE	Number of scheduled events	1-200		
NREQ	Number of men required by type	0-10		
NREQE	Number of men required by type for emergency			
NX	Next event number for each alternative	1-200		
PID	Average duration of physical incapacity	0-30	3	Time in days
PPFQ	Percent fully qualified in primary specialty	0-100	25	
PPMQ	Percent moderately qualified in primary specialty	0-100	50	
PPUQ	Percent unqualified in primary specialty	0-100	25	
PRB	Probability of each alternative path	0-1.0		
PTT	Cross training probability table	0-1.0		
PWRRT	Average short term power output	200-500	350	Calories expended
RELH	Equipment reliability	0-1000		Time in days
RELI	Intermittent reliability	0-1.0		
RTU	Repair touchup code	1-3		
SESTA	Sea state	0-9	3	
SIGWT	Standard deviation of body weight	0-50	15	Deviation in pounds
SLEEP	Number of hours since last eight hour sleep period	0-20	4	
SPFQ	Percent fully qualified in secondary speciality	0-100	25	
SPMQ	Percent minimally qualified in secondary specialty	0-100	50	
SPUQ	Percent unqualified in secondary speciality	0-100	25	
ST	Earliest starting time allowed	0-24		Time in hours
TFAT	Fatigue threshold	.10-.35	.25	
TL	Time limit by which event must be completed	0-24		Time in hours
TS	Consumable threshold set identifier (units/hours)	0-9999		
TSI	Consumable threshold set identifier (units)	0-9999		

Table 4-5. Input Data (Continued)

FORTRAN	Description	Range	Average	Remarks
TSE	Threshold set for consumables below which event is ignored (units/hours)	0-9999		
TSE1	Threshold set for consumables below which event is ignored (units)	0-9999		
TSR	Threshold set for consumables below which emergency is ignored (units/hours)	0-9999		
TSR1	Threshold set for consumables below which emergency is ignored (units)	0-9999		
TUI	Intermittent reliability	0-1000		Time in hours
WORK1	Number of hours worked after which no new work assignment is made	4-20	16	
WORK2	Number of hours worked after which no new work is authorized	4-16	10	
WT	Mean body weight	1-300	150	Weight in pounds
%PC	Physical capability constant	0-100	.25	

4.3 Use of the ISM

The model is designed to simulate a complete equipment or system mission or cruise cycle. The input data is used to simulate system operation, operator performance, equipment failure, and the performance of maintenance technicians during repair procedures. The procedure for using this model is summarized as follows:

- Perform an analysis for each task involved in the complete cycle and prepare a sequentially numbered list of subtasks for each task
- Develop other input data as outlined in table 4-5 and fill out input data forms provided in appendix D
- Prepare a "number of iterations" card (format 1)
- Prepare a Title card indicating the name of the mission being simulated (format 2)
- Prepare a tape input/number of days card (format 3)
- Prepare an input parameter card using information from the input data form for card format 4
- Prepare a personnel data card using the input data form for card format 5
- Prepare an equipment repair data card using the input data form for card format 6

- Prepare an emergency event data card for each anticipated emergency event using the input data forms for card format 7

- Prepare an event type data card for each event (from task analysis) using the input data forms for card format 8

- Prepare a scheduled event sequence data card for each scheduled event using the input data forms for card format 9

- Assemble the card deck and run the model

4.3.1 *Task Analysis.* A sequential list of the events involved in the simulated mission is required for the computer simulation. The list may be prepared from an available task analysis or by consultation with individuals knowledgeable in the events that occur during a mission such as the one being simulated. When all of the events have been identified, it is very helpful to prepare a time-line diagram which schedules the events over the duration of the mission, shown in figure 4-2. The time-line diagram must include scheduled task performance times for each operator or technician and all idle or waiting time. Each event is plotted on the time line, from the start of the mission, taking all relevant factors such as task interrelationships into account.

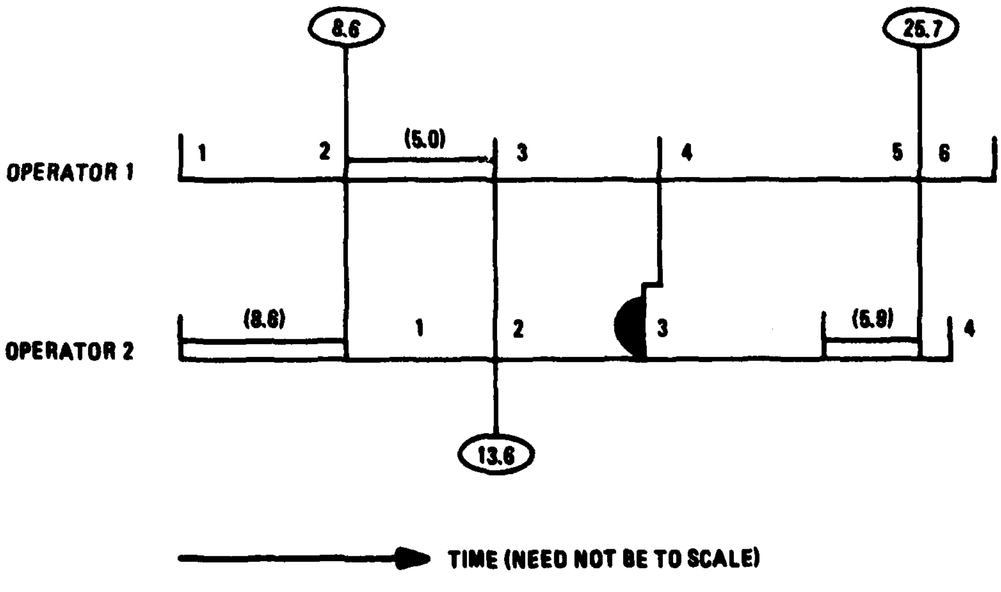

Figure 4-2. Time-Line Diagram

4.3.2 *Input Data Forms.* The input data forms in appendix B show the formats for preparing input data for card punching. The nine card formats used in the model are listed in table 4-6. In the NAME-LIST format, data are punched sequentially in card columns 2 through 72 without regard for column assignments. A comma separates each input number. Thus, all arrays must be completed with zeros. For example, the cross training probability matrix must have 10 x 10 entries even in the case that there are fewer than 10 types of personnel to be simulated.

If the simulation calls for more than one iteration, the input routine dumps all input data, except for the parameters and personnel data, onto a magnetic tape. This tape is then read in the subsequent iterations. A tape created in this fashion can be used to supply input for future simulations.

Table 4-6 Card Formats

Card Format	Type of Data
1	Number of iterations
2	Title
3	Tape input and number of days
4	Pa[illegible]ers
5	Pers[illegible]el
6	Equipment repair events
7	Emergency events
8	Event type data
9	Sequence data

4.3.3 *Number of iterations.* The "number of iterations" card (card format 1) contains only one line of data and indicates the number of iterations for the run.

4.3.4 *Title card.* The title card (card format 2) contains one line of data punched in card columns 2 through 72 and gives the name of the mission for identification purposes.

4.3.5 *Tape Input/Number of Days Card.* The tape input/number of days card (card format 3) contains two lines of data. The first line is used to select tape or card input option. When the data has been subsequently run on the model and the simulation calls for more than one iteration, the input routine dumps all input data except parameters (format 4) and personnel data (format 5) onto a magnetic tape which is then read in the subsequent iterations. A tape created in this fashion may be used to supply input for future simulations by selecting the tape option (code 000 = card option, 001 = tape option). The second line of the card inputs the number of days in the simulated mission.

4.3.6 *Input Parameter Card.* The input parameter card (card format 4) must be punched exactly in accordance with the format 4 input data forms, presented on six pages in appendix B. The input data items, which are defined in table 4-5, run sequentially across the card columns with each input data item separated by a comma, without regard for card column assignments. All arrays must be completely filled in; if a particular item is not applicable, fill in the array with zeros. When no consumables are being simulated, input "1" in every position in the two "initial value" arrays and input zeroes in all of the "consumable threshold" arrays shown on the input data forms. The model provides for monitoring the level of up to 10 selected consumables, which may be monitored on a unit expenditure basis, or monitored on a rate of expenditure (units per hour) basis. For each group, a secondary input allows specification of up to 10 threshold levels for each consumable. The specified consumable threshold level causes the model to ignore all tasks involving a particular consumable when the value of that consumable drops below the specified threshold level (except for repairs and emergencies).

4.3.7 *Personnel Data Card.* The personnel data card (card format 5) must be punched exactly in accordance with the two-sheet format 5 input data form shown in appendix B. The input data items, which are defined in table 4-5, run sequentially across the card columns with each item separated by a comma. All arrays must be completely filled in. Zeroes must be used for all items that are not applicable to the mission being simulated. The first data item on card 5 is average population body weight (WT). If a specific system is being simulated in which the body weights of its personnel are known to differ from those of the general population or the general military population, the mean weight and standard deviation of that specific system's manning tables become the input data. For all other circumstances, the mean weight and standard deviation may be obtained from any appropriate anthropometric tabulation (e.g., Damon, Stoudt, & McFarland, 1966; Webb, 1964; Hertzberg, Daniels, & Churchill, 1950). The cross-training probability table provides the likelihood values of a man of each type having been crossstrained in each secondary specialty. This table is a 10 x 10 array which provides for the input up to 10 primary and 10 secondary specialties. Table 4-7 is an example of a crosstraining probability matrix for 9 specialties giving the probability of each specialist cross training into each of the other specialties. When these cross-training variables are printed out by the program they will have been converted to the cumulative probability format used in the processing. If fewer than 10 specialties are being considered, fill in the remaining spaces with zeroes.

Table 4-7 Personnel Cross-training Data

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
1	0	0.30	0.05	0	0.30	0	0	0	0.1	0	0	0	0	0	Radar/sonar
2	0.20	0	0	0	0.25	0.05	0	0	0.03	0	0	0	0	0	Electronics technician
3	0.20	0.05	0	0	0.05	0	0	0.05	0.03	0	0	0	0	0	Nuclear reactor technician
4	0.05	0	0	0	0	0	0.10	0	0.03	0	0	0	0	0	Steam fitter
5	0.20	0.50	0	0	0	0	0	0.10	0.03	0	0	0	0	0	Electricians mate
6	0.10	0.30	0	0	0.30	0	0	0	0.03	0	0	0	0	0	Gunners mate
7	0.10	0.01	0.02	0.08	0.02	0.10	0	0	0.03	0	0	0	0	0	Boatswains mate
8	0.05	0	0	0	0	0	0	0	0.20	0	0	0	0	0	Pharmacists mate
9	0.05	0	0	0	0	0	0.05	0	0	0	0	0	0	0	Cook/baker

4.3.8 *Equipment Repair Data Cards.* An equipment repair data card (card format 6) may be prepared for each equipment repair family identified in the task analysis. Repair event families are divided into four categories as shown in table 4-8, with eight event families in each category. Each event family is further subdivided into subevents. The model is limited to 12 subevents per repair event family. (Subevents under scheduled non-repair event families are unlimited in number.)

4.3.9 *Emergency Event Cards.* An emergency event data card (card format 7) must be prepared for each type of anticipated emergency event. The cards must be punched exactly in accordance with the format 7 input data form presented in appendix D. The input data items, which are defined in table 4-5, are punched sequentially across the card columns, with each input data item separated by commas, without regard for card column assignments. There is no limit on the number of emergencies which may be simulated each simulated day.

Table 4-8 Repair Event Codes

Repair Events	Code	
	Number	FORTRAN
Electronic		
Uses reference manuals	6	EURM
Electronic cognition	7	EC
Electronic circuit analysis	8	ECA
Electronic repair	9	ER
Electronic equipment operation	10	EO
Electronic equipment inspection	11	EIP
Electronic instruction	12	EI
Electronic report	13	ERPT
Electrical		
Uses reference manuals	14	ELURM
Electrical cognition	15	ELC
Electrical analysis	16	ELA
Electrical repair	17	ELR
Electrical equipment operation	18	ELO
Electrical equipment inspection	19	ELEP
Electrical instruction	20	ELI
Electrical report	21	ELRPT
Electro-mechanical		
Uses reference manuals	22	EMRUM
Electro-mechanical cognition	23	EMC
Electro-mechanical analysis	24	EMA
Electro-mechanical repair	25	EMR
Electro-mechanical equipment operation	26	EMO
Electro-mechanical equipment inspection	27	EMEI
Electro-mechanical instruction	28	EMI
Electro-mechanical report	29	EMRPT
Mechanical		
Uses reference manuals	30	MURM
Mechanical cognition	31	MC
Mechanical analysis	32	MA
Mechanical repair	33	MR
Mechanical equipment operation	34	MO
Mechanical equipment inspection	35	MEI
Mechanical equipment instruction	36	MI
Mechanical report	37	MRPT

4.3.10 *Event Type Cards.* An event type data card (card format 8) must be prepared for each type of event scheduled for the mission. Input codes are given in the input data form presented in appendix B. Additional information about the event type input data items is provided in table 4-5.

4.3.11 *Scheduled Event Sequence Cards.* A scheduled events title card (card format 9) must be prepared for each iteration. The remaining scheduled events data shown on the format 9 input data form must be punched on a separate card for each scheduled event.

4.3.12 *Card Deck Assembly.* Assemble the card deck as shown in figure 4-3. The input data cards are arranged in numerical sequence with multiple event data cards of the same type arranged according to the time sequence in which they are to occur in the simulation.

4.4 Results of Computer Simulation

The ISM produces a variety of output data which are recorded on magnetic tape for subsequent printout on a high speed printer. The printouts available are listed and described in table 4-9. The model provides printouts of the input data for verification.

Table 4-9 Simulation Model Outputs

Type	Type of Printout	Frequency	Purpose
INPUT	Parameters	per run	Input verification
INPUT	Personnel data	per run	Input verification
INPUT	Equipment & repair events	per run	Input verification
INPUT	Emergencies	per run	Input verification
INPUT	Event type	per run	Input verification
OUTPUT	Start on mission crew data	per iteration	Crew rating data
OUTPUT	Failure/emerg. occurrences	per iteration	Simulated emergency data
OUTPUT	Scheduled event sequence	per day	Sequential listing of events
OUTPUT	Detail events	per event	
OUTPUT	End of day report	per day	
OUTPUT	End of iteration report	per iteration	
OUTPUT	Run summary	per run	

Various output printouts are available to present the results of the simulation. Recording and subsequent printout options are selected by the input data punched on card format 4, the input parameters card. The print options are given in table 4-10.

Table 4-10 Printout Options

Printout Description	FORTRAN	Input Codes	
		1	0
Parameter input data	IND (1)	Print all input data	Print parameter data only
Personnel input data	IND (1)	Print all input data	Print parameter data only
Equipment and repair event input data	IND (1)	Print all input data	Print parameter data only
Emergency event input data	IND (1)	Print all input data	Print parameter data only
Event type input data	IND (1)	Print all input data	Print parameter data only
Start of mission crew data	IND (2)	Print	Don't Print
Occurences of failures and emergencies	IND (3)	Print	Don't Print
Scheduled event sequence	IND (4)	Print	Don't Print
Detail events	IND (5)	Print	Don't Print
End of day report	IND (6)	Print	Don't Print
End of iteration	IND (7)	Print	Don't Print
Run Summary	–	No option	No option

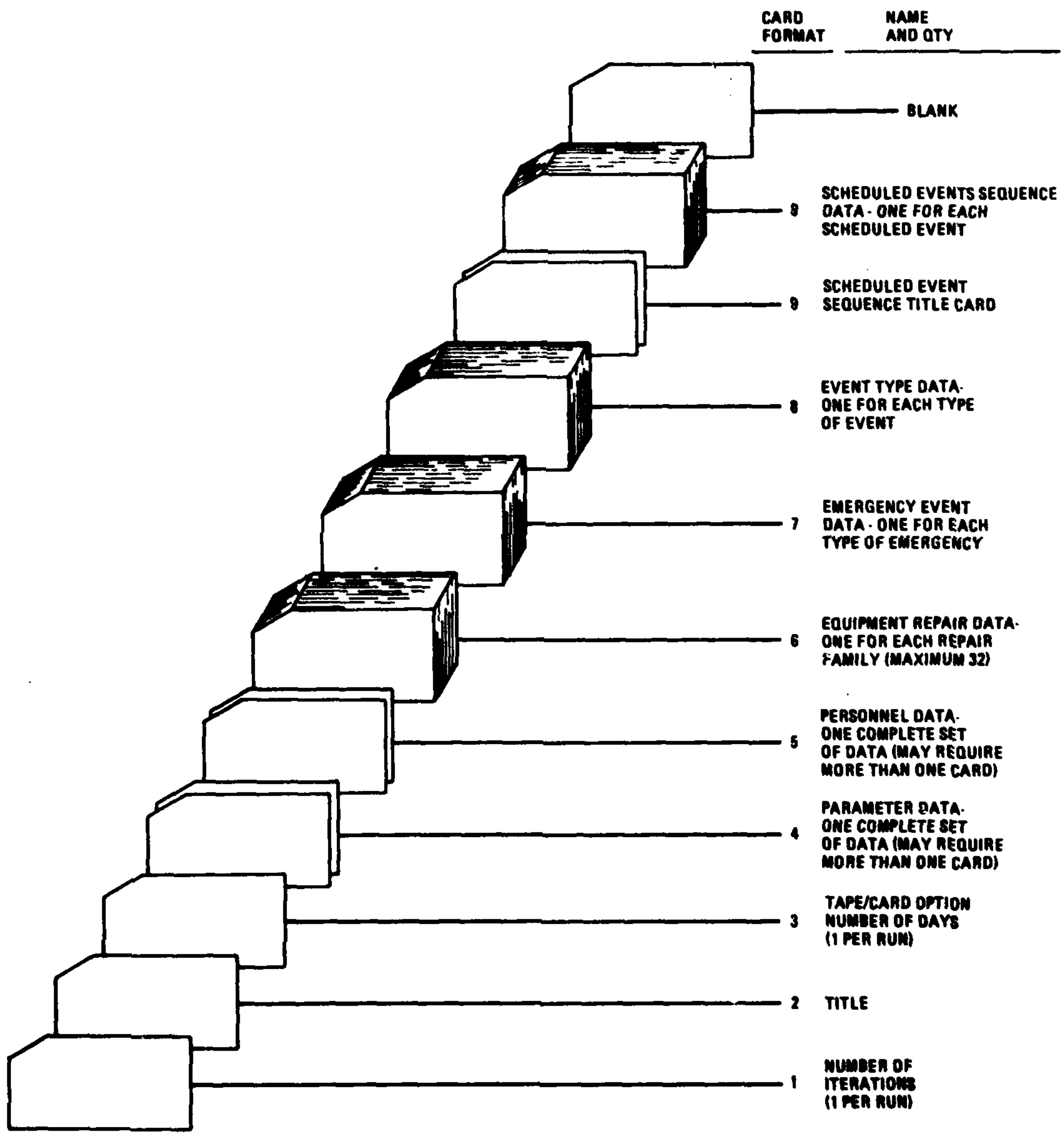

Figure 4-3. Card Deck Assembly

4.4.1 *Input Data Printouts.* Printouts of the input data are provided to allow the operator to verify source data. The following input data printouts are available:

- Parameters–The parameters printout (figure 4-4) provides a listing of the input parameter data from card format 4.

- Personnel Data–The personnel data printout (figure 4-5) provides a listing of the input personnel data from card format 5.

- Equipment and Repair Events–The equipment and repair events printout (figure 4-6) provides a listing of the input event data from card format 6.

- Emergency Event Data–The emergencies printout (figure 4-7) provides a listing of the input emergency event data from card format 7.

- Event Type–The event type printout (figure 4-8) provides a listing of the input event type data form card format 8.

4.4.2 *Start of Mission Crew Data.* The start of mission crew data printout, figure 4-9, combines the crew input data from the parameter and personnel input cards and provides a detailed listing of crew conditions as they exist at the start of the simulated mission. The last line of the listing shows average values which the model computes for the total crew.

4.4.3 *Failure and Emergency Occurrences.* The failure and emergency occurrences printout, figure 4-10 (print option 3), provides the simulated occurrence of the emergency events from format 7. The printout shows the first day in which each type of failure or emergency event will occur during the mission. The printout also shows the sea state at the start of the mission and the amount of personnel degradation resulting from sea sickness.

4.4.4 *Scheduled Event Sequence.* The scheduled event sequence data printout provides the information pertinent to the occurrence of events scheduled for the simulated mission. The scheduled events shown in figure 4-11 are divided into event type families, identified by numbers in the second column of the printout. If the event involves the use of consumables, information about the applicable consumables is provided in the next two columns (the threshold level and the number of units required for the event). The listing indicates the next event to be started after completion of each event (next event and probability) the event that must be completed before a particular event can be started (precedent event), the time after the beginning of the mission that the event should be started (start time), the time within the event must be completed (time limit), and the code for events not successfully completed on the first try: code 1 = Repeat, code 2 = touch-up, code 3 = go to next event.

4.4.5 *Detail Events.* If the option to record detailed event results is taken (print option 5, IND (5) = 1), the results are recorded and printed for analysis. Included in the printout are the following results for each event: successful/unsuccessful, men available, start time allowed, prior event requirements time finished, event start time, event duration, event end time, unmanned hours, group stress, physical capability, pace, aspiration, performance adequacy, hazard, consumables used and remaining, men on the job, and each man's fatigue, physical capacity, hours worked (cumulative), calories expended on this task, calories expended (cumulative) hours since sleep, idle hours, hours slept, cumulative performance, and aspiration, as shown in figure 4-12.

The printout for each event performed is concluded with data on each man who was assigned to the event. Here, an asterisk in the LDR column identifies the work group leader.

```
PARAMETER INPUTS FOR THIS  1 DAY RUN OF  3  MISSION ITERATIONS
     ENTITLED    AES HURT VALIDATION - RUN 6

- - - - AVERAGE CREW DATA - - - -
PACE   STRESS    ASPIR-  CALORIES REQD  POWER RATE
       THRESHOLD ATION      PER DAY      CALS/HR.
1.00     2.30     0.90       2400.        440.0

HOURS SINCE  CATNAP  MAXIMUM  --WORK LIMITS(HRS)--  -------THRESHOLDS------  ------------CONSTANTS--------------------
LAST SLEEP   LENGTH   SLEEP    NO MORE     NO MORE  FATIGUE  ESSENTIALITY   UNMANNED     LEADERS     PHYSICAL    STRESS
             (HRS)   PER DAY  ASSIGNMENTS  WORK                             STATION HRS  EXPECTATION CAPABILITY
   1.0        1.0      8.0      18.0       22.0     0.25          10           0.50         0.90        0.95      0.50

                                                                    NUMBER
                                              1.   2.   3.   4.   5.   6.   7.   8.   9.   10
INITIAL VALUE OF CONSUMABLES (UNITS)          1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
INITIAL VALUE OF CONSUMABLES (UNITS/HR)       1.   1.   1.   1.   1.   1.   1.   1.   1.   1.

                                      SET
CONSUMABLE THRESHOLDS (UNITS)          1      0.   0.   0.   0.   0.   0.   0.   0.   0.   0.
                                       2      0.   0.   0.   0.   0.   0.   0.   0.   0.   0.
                                       3      0.   0.   0.   0.   0.   0.   0.   0.   0.   0.
                                       4      0.   0.   0.   0.   0.   0.   0.   0.   0.   0.
                                       5      0.   0.   0.   0.   0.   0.   0.   0.   0.   0.
                                       6      0.   0.   0.   0.   0.   0.   0.   0.   0.   0.
                                       7      0.   0.   0.   0.   0.   0.   0.   0.   0.   0.
                                       8      0.   0.   0.   0.   0.   0.   0.   0.   0.   0.
                                       9      0.   0.   0.   0.   0.   0.   0.   0.   0.   0.
                                      10      0.   0.   0.   0.   0.   0.   0.   0.   0.   0.

CONSUMABLE THRESHOLDS (UNITS/HR)       1      0.   0.   0.   0.   0.   0.   0.   0.   0.   0.
                                       2      0.   0.   0.   0.   0.   0.   0.   0.   0.   0.
                                       3      0.   0.   0.   0.   0.   0.   0.   0.   0.   0.
                                       4      0.   0.   0.   0.   0.   0.   0.   0.   0.   0.
                                       5      0.   0.   0.   0.   0.   0.   0.   0.   0.   0.
                                       6      0.   0.   0.   0.   0.   0.   0.   0.   0.   0.
                                       7      0.   0.   0.   0.   0.   0.   0.   0.   0.   0.
                                       8      0.   0.   0.   0.   0.   0.   0.   0.   0.   0.
                                       9      0.   0.   0.   0.   0.   0.   0.   0.   0.   0.
                                      10      0.   0.   0.   0.   0.   0.   0.   0.   0.   0.

CUMMULATIVE PROBABILITY OF SEA STATES         0.   0.11 0.28 0.61 0.94 1.00 1.00 1.00 1.00 1.00
AVERAGE EQUIPMENT INTERMITTANT RELIABILITY    2.00 0.25 0.25 0.25
OUTPUT RECORDING OPTIONS                      1    1    1    1    1    1    1
```

Figure 4-4. Sample of Parameter Output Format

PERSONNEL DATA

- BODY WEIGHT - MEAN	SIGMA
160.5	20.0

SPECIALTY	FRACTION OF CREW QUALIFIED FULLY	MINIMALLY	UN
PRIMARY	1.00	0.	0.
SECONDARY	0.50	0.50	0.

MAN TYPE	CUMULATIVE CROSS TRAINING PROBABILITIES 1	2	3	4	5	6	7	8	9	10
1	1.00	1.01	1.00	1.00	1.06	1.06	1.06	1.06	1.06	1.06
2	0.30	0 [illegible]	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
3	0.90	.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
8	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

LEVEL	NUMBER OF MEN IN CREW BY TYPE 1	2	3	4	5	6	7	8	9	10
1	3	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	0	0	1	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0

CREW ASSIGNMENT TO SHIFTS BY MAN

SHIFT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	1	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
3	0	0	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0
4	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	1	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
6	0	0	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0

(1 - ASSIGNED 0 - UNASSIGNED)

--PHYSICAL CAPABILITY AVERAGES-- MAN DAYS PER INCIDENCE	DURATION	PHYSICAL CAPABILITY CONSTANT
10.00	1.0	3.00

Figure 4-5. Sample of Output of Personnel Input Data

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EQUIPMENT AND REPAIR EVENT DATA

EQUIP TYPE	DESCRIPTION	-CONSUM. (UNITS/HR)	THRESHOLD SET- (UNITS)	RELIABILITY (DAYS/FAIL)	TIME UNAVAIL	EVENTS/ FAMILY
1	CONSOLE1	0	0	0.750	0.06	7

EVENT TYPE	NEXT EVENT 1	NEXT EVENT 2	NEXT EVENT 3	PROBABILITY 1	PROBABILITY 2	PROBABILITY 3	REPEAT/ TOUCHUP	DATA CHG NO 1	DATA CHG NO 2	DATA CHG NO 3	DATA CHANGE VALUE 1	DATA CHANGE VALUE 2	DATA CHANGE VALUE 3	PREC. EVENT	FAMILY INDIC.	FAMILY NUMBER	DURATION TARGET	EVENT NUMBER IN FAMILY	EVENT NUMBER COMPUTER
8	203	202	202	0.30	0.70	0.	1	0	0	0	0.	0.	0.	0	1	1	0.08	1	201
7	203	203	203	1.00	0.	0.	1	0	0	0	0.	0.	0.	201	0	1	0.05	2	202
11	204	204	205	0.60	0.	0.40	1	0	0	0	0.	0.	0.	201	0	1	0.10	3	203
9	205	205	205	1.00	0.	0.	1	0	0	0	0.	0.	0.	203	0	1	0.12	4	204
10	206	207	207	0.50	0.	0.50	2	0	0	0	0.	0.	0.	203	0	1	0.10	5	205
12	207	207	207	1.00	0.	0.	1	0	0	0	0.	0.	0.	205	0	1	0.03	6	206
13	208	208	208	1.00	0.	0.	1	0	0	0	0.	0.	0.	205	2	1	0.04	7	207

EQUIP TYPE	DESCRIPTION	-CONSUM. (UNITS/HR)	THRESHOLD SET- (UNITS)	RELIABILITY (DAYS/FAIL)	TIME UNAVAIL	EVENTS/ FAMILY
2	CONSOLE 2	0	0	0.750	0.06	7

EVENT TYPE	NEXT EVENT 1	NEXT EVENT 2	NEXT EVENT 3	PROBABILITY 1	PROBABILITY 2	PROBABILITY 3	REPEAT/ TOUCHUP	DATA CHG NO 1	DATA CHG NO 2	DATA CHG NO 3	DATA CHANGE VALUE 1	DATA CHANGE VALUE 2	DATA CHANGE VALUE 3	PREC. EVENT	FAMILY INDIC.	FAMILY NUMBER	DURATION TARGET	EVENT NUMBER IN FAMILY	EVENT NUMBER COMPUTER
15	215	214	214	0.30	0.70	0.	1	0	0	0	0.	0.	0.	0	1	2	0.08	1	213
14	215	215	215	1.00	0.	0.	1	0	0	0	0.	0.	0.	213	0	2	0.05	2	214
18	216	216	217	0.60	0.	0.40	1	0	0	0	0.	0.	0.	213	0	2	0.10	3	215
16	217	217	217	1.00	0.	0.	1	0	0	0	0.	0.	0.	215	0	2	0.12	4	216
17	218	219	219	0.50	0.	0.50	2	0	0	0	0.	0.	0.	215	0	2	0.10	5	217
19	219	219	219	1.00	0.	0.	1	0	0	0	0.	0.	0.	217	0	2	0.03	6	218
20	212	212	212	1.00	0.	0.	1	0	0	0	0.	0.	0.	217	2	2	0.04	7	219

EQUIP TYPE	DESCRIPTION	-CONSUM. (UNITS/HR)	THRESHOLD SET- (UNITS)	RELIABILITY (DAYS/FAIL)	TIME UNAVAIL	EVENTS/ FAMILY
3	CONSOLE 3	0	0	0.750	0.06	7

EVENT TYPE	NEXT EVENT 1	NEXT EVENT 2	NEXT EVENT 3	PROBABILITY 1	PROBABILITY 2	PROBABILITY 3	REPEAT/ TOUCHUP	DATA CHG NO 1	DATA CHG NO 2	DATA CHG NO 3	DATA CHANGE VALUE 1	DATA CHANGE VALUE 2	DATA CHANGE VALUE 3	PREC. EVENT	FAMILY INDIC.	FAMILY NUMBER	DURATION TARGET	EVENT NUMBER IN FAMILY	EVENT NUMBER COMPUTER
22	227	226	226	0.30	0.70	0.	1	0	0	0	0.	0.	0.	0	1	3	0.08	1	225
21	227	227	227	1.00	0.	0.	1	0	0	0	0.	0.	0.	225	0	3	0.05	2	226
25	228	228	229	0.60	0.	0.40	1	0	0	0	0.	0.	0.	225	0	3	0.10	3	227
23	229	229	229	1.00	0.	0.	1	0	0	0	0.	0.	0.	227	0	3	0.12	4	228
24	230	231	231	0.50	0.	0.50	2	0	0	0	0.	0.	0.	227	0	3	0.10	5	229
26	231	231	231	1.00	0.	0.	1	0	0	0	0.	0.	0.	229	0	3	0.03	6	230
27	224	224	224	1.00	0.	0.	1	0	0	0	0.	0.	0.	[illegible]	2	3	0.04	7	231

Figure 4-6. Sample of Equipment and Repair Event Output Format

```
                                   EMERGENCY EVENT DATA

                                                                                --REPAIR TIME--   CONSUM THRESHOLD   SET
EMER   DESCRIPTION                                                                 AVG   SIGMA     (UNITS/HR)       UNITS
NO.
                                                                                  1.00   0.25          0              0
 1      FIRE
ESSEN-  MENTAL   HAZARD      NUMBER OF MEN REQUIRED                 CONSUMABLE EXPENDITURE RATE(UNITS/HR)   DAYS/     DURATION
TIALITY  LOAD              EXPECTED ENERGY CONSUMPTION (CAL/HR.)    CONSUMABLE EXPENDITURE RATE(UNITS)      EMERGENCY  TARGET
                            1   2   3   4   5   6   7   8   9  10    1  2  3  4  5  6  7  8  9 10
                                                                     0. 0. 0. 0. 0. 0. 0. 0. 0. 0.              5        1.20
  80      2.       4.       1   3   0   0   0   0   0   0   0   0    0  0  0  0  0  0  0  0  0  0
                          420 420   0   0   0   0   0   0   0   0
```

Figure 4-7. Sample of Emergency Event Output Format

```
                                                EVENT TYPE DATA

---------------------------------------------------------------------------------------------------------------------
 TYPE  IDENTIFIER                                                       DURATION     CLASS   NUMBER OF     EQUIPMENT
                                                                      AVG.  SIGMA            EQUIPS. REQD.  NUMBERS REQD
                                                                                                            1 2 3 4 5 6
---------------------------------------------------------------------------------------------------------------------
 ESSEN-  MENTAL  EVENT  TRAIN HAZARD        NUMBER OF MEN REQUIRED            CONSUMABLE EXPENDITURE RATE (UNITS/HR.)
 TIALITY  LOAD    KIND   CODE
---------------------------------------------------------------------------------------------------------------------
                                     CONSUMABLE EXPENDITURE RATE (UNITS)              EXPECTED ENERGY CONSUMPTION
                                     1  2  3  4  5  6  7  8  9  10       1     2     3    4    5    6    7    8    9   10
---------------------------------------------------------------------------------------------------------------------

 1     CHECK LOGS AND GEAR                                             0.430  0.050       3         3         1 2 3 0 0 0
 50       5.        2    1     2.    1  0  0  0  0  0  0  0  0  0       0.     0.    0.   0.   0.   0.   0.   0.   0.   0.
                                     0  0  0  0  0  0  0  0  0  0     160.     0.    0.   0.   0.   0.   0.   0.   0.   0.

 2     SEARCH AND DETECT                                               0.500  0.116       3         3         1 2 3 0 0 0
 90       5.        2    1     1.    0  1  0  0  0  0  0  0  0  0       0.     0.    0.   0.   0.   0.   0.   0.   0.   0.
                                     0  0  0  0  0  0  0  0  0  0       0.   170.    0.   0.   0.   0.   0.   0.   0.   0.

 3     PROSECUTE TARGET                                                0.200  0.040       3         0         0 0 0 0 0 0
 60       5.        2    1     1.    1  0  0  0  0  0  0  0  0  0       0.     0.    0.   0.   0.   0.   0.   0.   0.   0.
                                     0  0  0  0  0  0  0  0  0  0       0.   150.    0.   0.   0.   0.   0.   0.   0.   0.

 4     LOST TARGET                                                     1.050  0.201       3         3         1 2 3 0 0 0
 70       3.        2    1     1.    0  1  0  0  0  0  0  0  0  0       0.     0.    0.   0.   0.   0.   0.   0.   0.   0.
                                     0  0  0  0  0  0  0  0  0  0       0.   100.    0.   0.   0.   0.   0.   0.   0.   0.

 5     CLEANUP                                                         0.120  0.030       4         0         0 0 0 0 0 0
 90       1.        2    1     2.    0  0  1  0  0  0  0  0  0  0       0.     0.    0.   0.   0.   0.   0.   0.   0.   0.
                                     0  0  0  0  0  0  0  0  0  0       0.     0.  120.   0.   0.   0.   0.   0.   0.   0.

 6     BT DROPS                                                        0.400  0.040       2         0         0 0 0 0 0 0
 80       3.        2    1     3.    1  0  0  0  0  0  0  0  0  0       0.     0.    0.   0.   0.   0.   0.   0.   0.   0.
                                     0  0  0  0  0  0  0  0  0  0     150.     0.    0.   0.   0.   0.   0.   0.   0.   0.

 7     USES REFERENCE MANUALS                                          0.100  0.020       3         1         1 0 0 0 0 0
 80       6.        2    1     1.    0  1  0  0  0  0  0  0  0  0       0.     0.    0.   0.   0.   0.   0.   0.   0.   0.
                                     0  0  0  0  0  0  0  0  0  0       0.   110.    0.   0.   0.   0.   0.   0.   0.   0.

 8     ELECTRONIC COGNITION                                            0.060  0.010       3         1         1 0 0 0 0 0
 90       8.        2    1     1.    0  1  0  0  0  0  0  0  0  0       0.     0.    0.   0.   0.   0.   0.   0.   0.   0.
                                     0  0  0  0  0  0  0  0  0  0       0.    90.    0.   0.   0.   0.   0.   0.   0.   0.
```

Figure 4-8. Sample of Event Type Output Data Format

START OF MISSION CREW DATA

LEVEL	PHYS. CAPABIL	COMPETANCE PRIMARY	COMPETANCE SECONDARY	PACE	ASPIR-ATION	HRS SINCE LAST SLEEP	PHYSICAL INCAPACITY
1	1.166	0.834	0.657	0.994	0.831	1.242	1.000
2	0.984	0.889	0.643	1.029	0.906	0.961	1.000
3	1.019	0.783	0.573	1.176	0.876	0.961	1.000

MAN NO.	PHYS-CAPABIL	COMPETANCE PRIMARY	COMPETANCE SECONDARY	PACE	ASPIR-ATION	HRS SINCE LAST SLEEP	PHYSIC 1	INCAP 2	FAT-IGUE	STRESS THRESHOLD	CALOR-IES	POWER RATE	LEVEL	SPECIALTY PRIMARY	SPECIALTY SECONDARY
1	1.337	0.760	0.777	0.993	0.912	1.299	1.000	0	0.039	2.233	3200.	500.2	1	1	2
2	1.081	0.760	0.627	0.934	0.744	1.338	1.000	0	0.	2.767	2994.	475.5	1	1	1
3	1.000	0.773	0.565	1.051	0.837	1.089	1.000	0	0.067	1.467	2593.	479.3	1	1	2
4	1.092	0.932	0.761	1.086	0.962	1.030	1.000	0	0.086	2.100	2621.	488.5	2	2	1
5	1.096	0.944	0.754	1.120	0.894	1.554	1.000	0	0.122	2.556	2630.	492.2	2	2	3
6	0.471	0.931	0.622	1.042	0.915	0.871	1.000	0	0.037	2.391	2090.	383.1	2	2	3
7	1.065	0.825	0.619	1.021	0.966	0.904	1.000	0	0.071	2.637	2556.	468.6	2	2	4
8	1.029	0.736	0.609	1.137	0.796	0.688	1.000	0	0.040	2.273	2469.	452.6	2	2	3
9	0.755	0.741	0.573	1.008	0.909	0.521	1.000	0	0.	1.487	1911.	332.8	2	2	3
10	0.954	0.795	0.611	1.064	0.920	0.606	1.000	0	0.075	2.900	2291.	419.9	2	2	5
11	1.013	0.724	0.679	0.967	0.919	1.206	1.000	0	0.	3.248	2431.	449.7	2	2	1
12	1.057	0.730	0.694	0.874	0.945	1.042	1.000	0	0.111	2.769	2536.	464.9	2	2	3
13	0.905	0.700	0.693	0.967	0.946	1.185	1.000	0	0.	1.948	2172.	378.2	2	2	1
14	1.019	0.783	0.573	1.176	0.876	0.961	1.000	0	0.	2.269	2445.	448.2	3	3	3
AVGS/MAN	1.025	0.813	0.641	1.032	1.469	1.021	1.000	0.	0.046	2.380	2460.	451.1			

Figure 4-9. Start of Mission Crew Data

Print Option Three - Occurences of Failures and Emergencies, Sea State and Sickness

Equipment Type	Day of First Occurrence	Emergency Type	Day of First Occurrence	Initial Sea State	Seasickness Degradation to Initial Competence
1	1	1	1	2	0.1110
2	1				
3	1				

Figure 4-10. Sample of Occurrences of Failures and Emergencies Output Format

SCHEDULED EVENT SEQUENCE DATA

FOR 177 SCHEDULED EVENTS OF DAY 1 ENTITLED DAY 1 TEST

RTU CODE
1-REPEAT
2-TOUCHUP
3-NEXT EVENT

EVENT NO.	TYPE	THRESHOLD SET UNITS/HR	UNITS	NEXT EVENT AND PROBABILITY 1		2		3		PRECEDENT EVENT NO.	START TIME	TIME LIMIT	REPEAT/TOUCHUP CODE
1	1	0	0	2	1.00	2	0.	2	0.	0	0.	4.00	2
2	2	0	0	3	1.00	3	0.	3	0.	0	0.	4.00	2
3	2	0	0	4	1.00	4	0.	4	0.	0	0.04	4.00	2
4	4	0	0	5	1.00	5	0.	5	0.	0	0.10	4.00	2
5	6	0	0	6	1.00	6	0.	6	0.	1	0.	4.00	2
6	2	0	0	7	1.00	7	0.	7	0.	0	0.61	4.00	2
7	2	0	0	8	1.00	8	0.	8	0.	0	0.66	4.00	2
8	3	0	0	9	1.00	9	0.	9	0.	2	0.	4.00	2
9	3	0	0	10	1.00	10	0.	10	0.	3	0.	4.00	2
10	2	0	0	11	1.00	11	0.	11	0.	0	1.15	4.00	2
11	2	0	0	12	1.00	12	0.	12	0.	0	1.19	4.00	2
12	3	0	0	13	1.00	13	0.	13	0.	6	0.	4.00	2
13	3	0	0	14	1.00	14	0.	14	0.	7	0.	4.00	2
14	4	0	0	15	1.00	15	0.	15	0.	0	1.47	4.00	2
15	3	0	0	16	1.00	16	0.	16	0.	10	0.	4.00	2
16	2	0	0	17	1.00	17	0.	17	0.	0	1.77	4.00	2
17	3	0	0	18	1.00	18	0.	18	0.	11	0.	4.00	2
18	2	0	0	19	1.00	19	0.	19	0.	0	1.99	4.00	2
19	2	0	0	20	1.00	20	0.	20	0.	0	2.35	4.00	2
20	3	0	0	21	1.00	21	0.	21	0.	16	0.	4.00	2
21	2	0	0	22	1.00	22	0.	22	0.	0	2.56	4.00	2
22	3	0	0	23	1.00	23	0.	23	0.	18	0.	4.00	2
23	4	0	0	24	1.00	24	0.	24	0.	0	2.86	4.00	2
24	2	0	0	25	1.00	25	0.	25	0.	0	2.94	4.00	2

Figure 4-11. Sample of Scheduled Event Sequence Output Format

```
REPAIR OF EQUIPMENT TYPE 3    EVENT TYPE 27         S
  IDENTIFIER  CONSOLE 3
 MEN AVAIL10.87  START ALLOWED  0.    PRIOR EVENT 229 FINISHED 10.82 EVENT STARTS 10.87 LASTS  0.08 ENDS 10.95 UNMANNED HRS   0.
 GROUP STRESS 1.00 PHYS CAP 1.04 PACE 1.1  ASP 0.85 PERF AD  0.79 HAZARD 0.1        EVENT CLASS    4
 CONS. USED(UNITS/HR.)        0     0     0     0     0     0     0     0     0     0
 CONS. LEFT(UNITS/HR.)        1     1     1     1     1     1     1     1     1     1
 CONS. USED(UNITS)            0     0     0     0     0     0     0     0     0     0
 CONS. LEFT(UNITS)            1     1     1     1     1     1     1     1     1     1

 MAN TYPE  SPEC   LDR RANK FATIGUE PHYS CAP HRS WRKD CALORIES CALS*HRS SINCE SLEEP IDLE HRS SLEPT CUM PERF  ASP
 10    2    P      *    2  0.444     1.042     3.12       7.5     619.4        12.0  0.        0.      1.00 0.85

 SCHEDULED EVENT    70  DAY  1  ITERATION  3        S
 MEN AVAIL10.95  START ALLOWED  9.15 PRIOR EVENT    0 FINISHED  0.   EVENT STARTS 10.95 LASTS  0.71 ENDS 11.66 UNMANNED HRS   0.
 GROUP STRESS 1.00 PHYS CAP 1.04 PACE 1.1  ASP 0.85 PERF AD  0.79 HAZARD 0.7        EVENT CLASS    3
 CONS. USED(UNITS/HR.)        0     0     0     0     0     0     0     0     0     0
 CONS. LEFT(UNITS/HR.)        1     1     1     1     1     1     1     1     1     1
 CONS. USED(UNITS)            0     0     0     0     0     0     0     0     0     0
 CONS. LEFT(UNITS)            1     1     1     1     1     1     1     1     1     1

 MAN TYPE  SPEC  LDR LEVEL FATIGUE PHYS CAP HRS WRKD CALORIES CALS*HRS SINCE SLEEP IDLE HRS SLEPT CUM PERF  ASP
 10    2    P      *    2  0.461     1.039     3.83     116.6     736.0        12.7  0.        0.      1.00 0.86

 EMERGENCY EVENT     1  DAY  1  ITERATION  3        S
 MEN AVAIL24.00  START ALLOWED  0.    PRIOR EVENT    0 FINISHED  0.   EVENT STARTS 24.00 LASTS  0.   ENDS 24.00 UNMANNED HRS   2.16
 GROUP STRESS 2.72 PHYS CAP 1.07 PACE 0.9  ASP 0.83 PERF AD  0.91 HAZARD 0.         EVENT CLASS    5
 CONS. USED(UNITS/HR.)        0     0     0     0     0     0     0     0     0     0
 CONS. LEFT(UNITS/HR.)        1     1     1     1     1     1     1     1     1     1
 CONS. USED(UNITS)            0     0     0     0     0     0     0     0     0     0
 CONS. LEFT(UNITS)            1     1     1     1     1     1     1     1     1     1

 MAN TYPE  SPEC  LDR LEVEL FATIGUE PHYS CAP HRS WRKD CALORIES CALS*HRS SINCE SLEEP IDLE HRS SLEPT CUM PERF  ASP
  3    1    P      *    1  0.101     1.101     4.00       0.      100.0         4.6  0.        7.5     0.73 0.72
  6    2    P           2  0.        1.004     7.25       0.        0.          0.8  0.1       7.6     0.53 0.50
  5    2    P           2  0.        1.113     7.40       0.        0.          3.5  0.4       7.9     1.00 1.00
  4    2    P           2  0.049     1.010     7.03       0.        0.          2.3  0.0       7.5     1.00 1.00

 SCHEDULED EVENT   172  DAY  1  ITERATION  3 IS IGNORED DUE TO  NO TIME AVAILABLE

 SCHEDULED EVENT   104  DAY  1  ITERATION  3        U
 MEN AVAIL13.47  START ALLOWED 13.47 PRIOR EVENT    0 FINISHED  0.   EVENT STARTS 13.47 LASTS  1.02 ENDS 14.49 UNMANNED HRS   0.
 GROUP STRESS 1.00 PHYS CAP 0.90 PACE 0.7  ASP 1.00 PERF AD  0.84 HAZARD 1.0        EVENT CLASS    3
 CONS. USED(UNITS/HR.)        0     0     0     0     0     0     0     0     0     0
 CONS. LEFT(UNITS/HR.)        1     1     1     1     1     1     1     1     1     1
 CONS. USED(UNITS)            0     0     0     0     0     0     0     0     0     0
 CONS. LEFT(UNITS)            1     1     1     1     1     1     1     1     1     1

 MAN TYPE  SPEC  LDR LEVEL FATIGUE PHYS CAP HRS WRKD CALORIES CALS*HRS SINCE SLEEP IDLE HRS SLEPT CUM PERF  ASP
  6    2    P      *    2  0.675     0.901     6.39     175.3    1231.9        15.5  0.        0.      0.45 1.00
```

Figure 4-12. Samples of Detail Event Output Format

4.4.6 *End of Day Reports.* If the option to print end-of day results is taken (print option 6, IND (6) = 1), the summarized results of the day just simulated are recorded for printout on the computer's high speed line printer. Figure 4-13 shows a sample tabulation. The first section provides summarized event and status information for the overall crew performance. Most of the headings shown are self explanatory. All times are given in hours. The AVG PERF ADEQ (average preformance adequacy, third line) is a mean of the performance adequacy value of all events performed. The AVG FAIL DIFF (average failure difference) is a mean, taken only for failed events, indicating the difference between performance adequacy (PA) and the required performance level, CASP(LI) · K7. The second section shows important data summarized by man. These results are either totals for all daily activity (hours worked, slept, idle, number of events successfully performed), or represent end-of-day conditions (fatigue, aspiration, competence). Averages for all of the elements in the second section follow the individual crew member summaries and represent daily summaries for simulated variables for the member summaries and represent daily summaries for simulated variables for the day. These summaries include: the total number of events scheduled, events worked, repair events, emergency events, repeated events, successes, failures and ignores, total hours worked, time spent on scheduled and repair and emergency events, unmanned station hours, average performance adequacy, average failure difference percentage of tasks failed and succeeded on first try, percentage of tasks succeeded on second try, and percentage of tasks ignored and repeated. Also, presented are: the safety index, competence increase, confidence, hazard, consumable balances, maximum stress and on which event, maximum mental load and on which event, maximum calories expended and on which event. A summary table is presented including for each man his physical capacity, hours worked in primary specialty, hours worked in secondary specialty, hours slept, hours idle, fatigue level, health index, average physical workload, competence, aspiration, performance (cumulative) and number of successes, Each of these variables is also averaged across the entire crew. A summary table of these variables is also presented by type of man.

Eleven reliability related variables are also summarized in the end-of-day printout. These are: Human Reliability (HR), Human Availability (HA), Human Mean Time to Repair (HMTTR), Equipment Reliability (ER), Equipment Availability (EA), Equipment Mean Time Between Failures (EMTBF), Equipment Mean Time to Repair (EMTTR), System Reliability (SR), System Availability (SA), and System Mean Time to Repair (SMTTR).

These same items are given in the third section of the each of day recording as a mean by type of man, where type is generally synonymous with work specialty.

4.4.7 *End of Iteration Reports.* If the option to print end of iteration reports is taken (print option 7, IND (7) = 1), the summarized results each iteration are recorded for printout. Figure 4-14 shows a sample tabulation. The resulting printout contains such summary items as: number of events successful on first and second try, number of events failed and ignored, average man hours spent in primary specialty, in secondary specialty, hours spent sleeping and hours idle, consumables remaining, averages of physical load, mental load, competence, average performance adequacy, average fatigue, average aspiration, average health, and average safety. Each of these variables is also summarized as percentage of total, average per day, or percentage of original, whichever is appropriate. Summary by day (including an average across days) includes: number of repair or emergency events, average man hours spent doing repairs or handling emergencies, maximum stress, maximum mental load, confidence, hazard, average failure difference, number of successes and unmanned hours. A summary table by day and man type is provided for the following variables: physical capability, hours spent on primary and secondary specialties, sleep time, idle time, fatigue, health index, average physical work load, competence, aspiration, cumulative performance, and number of successes. Averages for these variables across types by day are also provided.

Reliability metrics provided at the end of each iteration are human mean time between failure (HMTBF), equipment mean time between failure (EMTBF), human mean time to repair (HMTTR), equipment mean time to repair (EMTTR), human availability (HAVAIL), and equipment availability (EAVAILL). A composite reliability metric system availability (SYSAVAIL) is also provided.

```
REPORT FOR DAY  1. ITERATION  1
 NO. EVENTS--TOTAL 184   SCHEDULED 146   REPAIR   3   EMERGENCY   1   REPEATS   0   SUCCESSES 168   FAILURES   0   IGNORES  16
 HOURS WORKED---TOTAL  80.5  SCHEDULED  74.9  REPAIR    2.9  EMER.    2.6  UNMANNED    5.7  AVG PERF ADEQ 0.92 AVG FAIL DIFF 0.
 PERCENTAGE OF---FAILURE  0.    SUCC. 1ST TRY 91.3  SUCC. 2ND TRY  0.    IGNORED  8.7  REPEATS  0.
 SAFETY INDEX  0.98                         MENTAL LOAD    0.48  PERF EFF    1.026  HAZARD    92.    EQUIPMENT REPAIR TIME  2.9
 MAX. STRESS  2.67 ON EVENT 561  MAX. MENTAL LOAD  7. ON EVENT  62  MAX. CAL. EXPENDED    1074. ON EVENT 561 SEA STATE  2
CONS. BAL. (UNITS)             1     1     1     1     1     1     1     1     1     1
CONS. BAL. (UNITS/HR)          1     1     1     1     1     1     1     1     1     1

MAN  TYPE  PHYSICAL  HOURS WORKED  SLEPT  IDLE  FATIGUE  HEALTH  AVG PHYS  COMPETENCE  ASPIRATION  PERFORM  NUMBER
NO.          CAP.    PRIM.   2ND                          INDEX  WORKLOAD                            CUM.    SUCC.
  1    1    1.235    4.93   0.        7.7  11.3     0.10   1.00     0.02       0.918       0.77     1.00     22.
  2    1    1.018    4.95   0.        3.6  15.4     0.66   1.00     0.05       0.975       0.79     1.00     23.
  3    1    0.945    6.34   0.        7.5  10.2     0.15   1.00     0.06       0.943       0.80     1.00     20.
  4    2    1.002    7.90   0.        7.5   8.6     0.10   0.94     0.23       0.969       0.99     1.00      9.
  5    2    1.029    7.90   0.        7.5   8.6     0.09   0.90     0.22       0.897       0.90     1.00      8.
  6    2    0.989    7.92   0.        7.5   8.6     0.04   1.00     0.26       0.938       0.96     1.00     11.
  7    2    1.045    7.36   0.22      7.5   8.9     0.40   1.00     0.24       0.990       0.96     1.00     10.
  8    2    1.132    7.74   0.        3.5  12.8     0.54   1.00     0.23       0.941       0.87     1.00     12.
  9    2    0.883    7.65   0.        6.4   9.9     0.35   1.00     0.26       0.955       0.94     1.00     15.
 10    2    0.814    8.60   0.        6.9   8.4     0.30   1.00     0.35       0.936       0.86     1.00     13.
 11    2    1.012    8.60   0.        7.6   7.8     0.17   1.00     0.31       0.957       0.86     1.00     10.
 12    3    1.007    0.26   0.        8.0  15.7     0.     1.00     0.00       0.969       1.00     1.00      2.

AVERAGES
 PER MAN    1.007    6.69   0.02      6.8  10.5     0.24   0.99     0.19       0.948       0.89     1.00     14.25

AVERAGES BY TYPE
  NO  TYPE
   3    1   1.066    5.41   0.        6.3  12.3     0.3    1.00     0.05       0.945       0.79     1.00   21.67
   8    2   0.974    7.97   0.03      6.8   9.2     0.25   0.98     0.26       0.947       0.92     1.00   13.00
   1    3   1.007    0.26   0.        8.0  15.7     0.     1.00     0.00       0.969       1.00     1.00    2.00


DAILY PERFORMANCE OF EQUIPMENT
               AVG. REPAIR TIME      UP    PERFORMANCE
     EQUIPMENT EXPECTED    ACTUAL TIME   LEVEL  EFFIC
         1       0.82       1.12 61.79   0.98     -
         2       0.82       0.97 61.79   0.98
         3       0.82       0.83 61.79   0.99


AVERAGES                0.82       0.98 61.79   0.98   0.83

SUMMARY BY EVENT CLASS
EVENT      NO. OF    HOURS WORKED    -----PERCENT OF TIME----   PERFORM. AVG. FAILURE
CLASS      EVENTS      PRIM    2ND   SUC1  SUC2  FAIL  IGNORE  ADEQUACY  DIFFERENCE
  2          6.        0.47   0.     100     0     0      0      0.91      -0.17
  3        159.        0.46   0.      91     0     0      9      0.84      -0.12
  4         18.        0.12   0.01    89     0     0     11      0.82      -0.09
  5          1.        2.60   0.     100     0     0      0      1.02      -0.30
```

Figure 4-13. Sample of End of Day Output Format

```
AVERAGES BY TYPE OF PERSONNEL

NO.  TYPE  PHYSICAL  HOURS WORKED  SLEPT  IDLE  FATIGUE  HEALTH  AVG PHYS  COMPETENCE  ASPIRATION   PERFORM        NUMBER
           CAP.      PRIM.   2ND                         INDEX   WORKLOAD                            CUM.           SUCC.
 3    1    1.006     5.400  0.      0.29  12.3   0.3     1.00    0.05      0.94        0.707        1.00           21.67
 8    2    0.974     7.969  0.03    6.01   9.2   0.2     0.98    0.26      0.95        0.918        1.00           13.00
 1    3    1.007     0.264  0.      0.00  15.7   0.      1.00    0.00      0.97        1.000        1.00            2.00

AVERAGES PER DAY FOR EACH MAN
 1    1    1.285     4.938  0.      7.72  11.3   0.1     1.00    0.02      0.92        0.769        1.00           22.00
 2    1    1.018     4.952  0.      3.68  15.4   0.7     1.00    0.05      0.97        0.794        1.00           23.00
 3    1    0.945     6.343  0.      7.50  10.2   0.2     1.00    0.06      0.94        0.798        1.00           20.00
 4    2    1.002     7.900  0.      7.50   8.6   0.1     0.94    0.23      0.97        0.991        1.00            9.00
 5    2    1.029     7.900  0.      7.50   8.6   0.1     0.98    0.22      0.99        0.900        1.00            8.00
 6    2    0.939     7.920  0.      7.50   8.6   0.0     1.00    0.26      0.93        0.960        1.00           11.00
 7    2    1.005     7.363  0.22    7.52   8.9   0.4     1.00    0.24      0.99        0.963        1.00           18.00
 8    2    1.127     7.740  0.      3.50  12.8   0.5     1.00    0.23      0.94        0.070        1.00           12.00
 9    2    0.883     7.653  0.      6.43   9.9   0.4     1.00    0.26      0.95        0.943        1.00           19.00
10    2    0.814     8.680  0.      6.95   8.4   0.3     1.00    0.35      0.94        0.895        1.00           13.00
11    2    1.012     8.500  0.      7.60   7.8   0.2     1.00    0.31      0.96        0.800        1.00           10.00
12    3    1.007     0.264  0.      0.00  15.7   0.      1.00    0.00      0.97        1.000        1.00            2.00

AVERAGES   1.007     6.607  0.02    6.70  10.5   0.2     0.99    0.19      0.95        0.892        1.00           14.25

REPORT FOR ITERATION  1 OF  1 DAY MISSION---
DAY     NUMBER OF EVENTS        AVE. MAN HOURS SPENT                     ----------END OF DAY AVERAGES----------  INDICES
    SUC1 SUC2 FAIL IGNORE   PRIM. SECOND  SLEEP   IDLE                   PHYS LD  MEN LD  COMP   APA   FAT.  ASP  HLTH  SFTY
  1 160.   0.   0.    16.   6.69   0.02   6.70  10.52                     0.19    0.40 0.940  0.92  0.24 0.89  0.99  0.98

   ---PERCENT OF TOTAL---   AVERAGE PER DAY PER MAN                                    AVERAGE PER DAY
   91.3  0.   0.     8.7    6.69   0.02   6.78  10.52                     0.19    0.40 0.940  0.92  0.24 0.89  0.99  0.98

CONS. BAL. (UNITS/HR)      1    1    1    1    1    1    1    1    1    1
PERCENT OF ORIGINAL      100  100  100  100  100  100  100  100  100  100
CONS. BAL. (UNITS)         1    1    1    1    1    1    1    1    1    1
PERCENT OF ORIGINAL      100  100  100  100  100  100  100  100  100  100

      -----NUMBER OF EVENTS-----  AVE. MAN HOURS SPENT  REPAIR   MAX.    MAX.    PERF.           AVE.FL  NUMBER    UNMANNED  SEA
  DAY  SCHLD REPAIR EMER  REPEAT REPAIR SUC2 EMERGENCY  TIME    STRESS  MEN LD   EFF.   HAZARD  DIFF    SUCC.     HOURS     STATE
    1   177    3     1      0     2.9   0.    2.6       2.93    2.67    6.70    1.026   92.25   0.      160       5.60      2.0

AVG/DAY 177    3     1      0     2.9   0.    2.6       2.93    2.67    6.70    1.026   92.25   0.      160       5.60      2.0

SUMMARY BY EVENT CLASS
EVENT     NO. OF    HOURS WORKED    ---PERCENT OF TIME----    PERFORM.  AVG. FAILURE
CLASS     EVENTS    PRIM    2ND     SUC1  SUC2  FAIL  IGNORE  ADEQUACY  DIFFERENCE
  2         6.      0.47    0.      100    0     0      0     0.91       -0.17
  3       150.      0.46    0.       91    0     0      9     0.84       -0.12
  4        18.      0.12    0.01     89    0     0     11     0.82       -0.09
  5         1.      2.60    0.      100    0     0      0     1.02       -0.30


EQUIPMENT PERFORMANCE FOR ITERATION  1

DAY  AVG. REPAIR TIME/EQUIP     UP      PERFORMANCE
       EXPECTED    ACTUAL      TIME    LEVEL EFFIC
 1       0.82       0.98      61.79    0.98  0.83

AVG.     0.82       0.98      61.79    0.98  0.83
```

Figure 4-14. Sample of End of Iteration Output Format

4.4.8 *Run Summary*. After each mission iteration, the model instructs the computer to make a check to determine whether all required iterations have been completed, if not, the process continues to the next iteration. If all scheduled iterations have been completed, the results of all iterations are summarized. The run summary tabulation (as shown in figure 4-15) is presented in a form similar to the iteration summary.

4.5 Use of Simulation Data

The simulation model is used to measure system and personnel effectiveness for a given set of parameters, or to measure the result of changes in variable input items. Examples are provided in the following paragraphs showing the effects of changes in input values for:

- Workday length and proficiency
- Average crew pace
- Sea state
- Crew size

The nominal input values for these parameters are shown in table 4-11. The matrix shown in table 4-7 was used in the assignment of personnel crosstraining probabilities. This matrix presents the probability of a personnel type with a given primary specialty being crosstrained in a given secondary specialty (the values in this matrix were used by Applied Psychological Services (APS) to validate the model). The examples presented in the following paragraphs are based on the results of simulation model sensitivity tests performed by APS, in which selected input parameters were varied to measure the resulting changes in system effectiveness. The parameters tested are shown in table 4-12 and the tests are described in the following paragraphs.

Table 4-11 "Standard" Parameter Set Run Conditions

Parameter	FORTRAN	Value
Average psychological stress threshold	APST	2.30
Workday, assignment limit	WORK 1	varied
Workday, maximum	WORK 2	22.00
Hours since last sleep at start	SLEEP	1.00
Catnap threshold	CN	1.00
Maximum sleep permitted per day	MAXSL	8.00
Fatigue threshold	TFAT	0.25
Average crew pace	ACP	varied
Average daily calories per crew member	CALRY	2700.00

Table 4-11 "Standard" Parameter Set Run Conditions (Continued)

Parameter	FORTRAN	Value
Average short term power rate (cals/hr)	PWRRT	440.00
Acceptable performance constant	K7	1.00
Work factor constant	K1	0.95
Consumable levels: (units/hr)	KON(1)	15150.00
	KON(2)	10000.00
	KON(3)	6000.00
	KON(4)	500.00
	KON(5)	500.00
	KON(6)	500.00
	KON(7)	500.00
	KON(8)	500.00
	KON(9)	500.00
	KON(10)	500.00
Consumable levels: (units)	KON1(1)	100.00
	KON1(2)	100.00
	KON1(3)	100.00
	KON1(4)	100.00
	KON1(5)	100.00
	KON1(6)	100.00
	KON1(7)	100.00
	KON1(8)	100.00
	KON1(9)	100.00
	KON1(10)	100.00
Initial aspiration level	AASP	0.85
Number of iterations	N	5.00
Essentiality threshold	IET	0.30
Sea state	SESTA	varied

Personnel Data	FORTRAN	Value
Mean body weight of total population	WT	160.50
Standard deviation of population body weight	SIGWT	20.00
% crew fully qualified in prime specialty	PPFQ	varied
% crew minimally qualified in prime specialty	PPMQ	varied
% crew unqualified in prime specialty	PPUQ	varied
% crew fully qualified in second specialty	SPFQ	varied
% crew minimally qualified in second specialty	SPMQ	varied
% crew unqualified in second specialty	SPUQ	varied
Avg. N man days between physical incapacitations	MPI	5.00
Avg. duration of incapacity (days)	PID	5.00
Physical capability constant, a value yielding zero		
Physical capability due to over exertion	ZPC	2.00
Number of men by type	MEN(ICE, NI)	varied

```
RUN SUMMARY FOR  3 ITERATIONS OF  1-DAY MISSION
ITER      NUMBER OF EVENTS           AVE. MAN HOURS SPENT                    -----------END OF DAY AVERAGES-----------  INDICES
      SUC1 SUC2 FAIL IGNORE   PRIM.  SECOND  SLEEP   IDLE        PHYS LD  MEN LD  COMP   APA   FAT.  ASP   HLTH  SFTY
      ---PERCENT OF TOTAL---         AVERAGE PER DAY                                AVERAGE PER DAY
  1   88.0  6.0  6.0   0.3    6.22   0.03    6.45   11.29         0.17     0.48 0.014  0.88  0.26 0.89  1.00  0.99
  2   65.2 15.0 15.0   4.8    6.60   0.02    6.20   11.11         0.16     0.50 0.006  0.86  0.24 0.87  0.99  0.98
  3   56.6 18.9 19.7   4.8    7.20   0.02    6.43   10.36         0.21     0.47 0.023  0.85  0.31 0.88  1.00  0.98

AVERAGES/ITERATION
      67.3 13.6 13.9   5.32   6.67   0.02    6.39   10.92         0.18     0.49 0.014  0.86  0.27 0.88  1.00  0.98

CONSUMABLES BALANCE - PERCENTAGE OF ORIGINAL
                        (UNITS PER HOUR)                                                  (UNITS)
ITER     1     2     3     4     5     6     7     8     9    10        1     2     3     4     5     6     7     8     9    10
 1   100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0    100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0
 2   100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0    100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0
 3   100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0    100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0

 AVG. 100.0 100.0 100.0 100.0 100.7 100.0 100.4 100.0 100.0 100.0   100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0

ITER  NUMBER OF EVENTS     AVE. MAN HOURS SPENT    MAX STRESS  MAX MEN LD   PERF EFF  HAZARD     AVG FAIL  NUMBER   UNMANNED  SEA
        REPAIR   EMER      REPT  REPAIR EMERGENCY                                                 DIFF     SUCC.      HOURS STATE
  1       2       1        13    2.1     2.5          2.75        7.98      0.987  97.846       0.013     165     10.154   1.0
  2       3       0        31    2.3     0.           2.19        7.92      1.000 106.392       0.058     166      4.560   3.0
  3       5       1        44    5.1     4.5          3.45        9.60      0.957 115.374       0.037     172      9.340   4.0

AVERAGES/ITERATION/DAY
          3.3     0.7      29.3  3.1     2.4          2.79        9.47      0.982 106.54        0.036   167.67     8.92    2.7


AVERAGES BY TYPE OF PERSONNEL

   TYPE  PHYSICAL  HOURS WORKED   SLEPT  IDLE  FATIGUE  HEALTH  AVG PHYS  COMPETENCE  ASPIRATION  PERFORM
           CAP.    PRIM.   2ND                           INDEX  WORKLOAD                            CUM.
    1     1.050    5.99   0.       6.0   11.4    0.19    1.00     0.05       0.822        0.89      0.93
    2     0.939    7.55   0.03     6.1   10.3    0.31    0.99     0.24       0.816        0.86      0.90
    3     1.033    0.20   0.       0.0   15.7    0.19    1.00     0.00       0.774        0.00      0.00

SUMMARY BY EVENT CLASS
EVENT    NO. OF    HOURS WORKED    ----PERCENT OF TIME----   PERFORM. AVG. FAILURE
CLASS    EVENTS    PRIM    2ND     SUC1  SUC2  FAIL IGNORE   ADEQUACY  DIFFERENCE
  2        7.      0.45   0.       80    10    10     0       0.87       -0.06
  3      102.      0.47   0.       69    13    14     5       0.82       -0.05
  4       19.      0.11   0.02     59    21    21     0       0.75       -0.03
  9        1.      3.55   0.      100     0     0     0       0.92       -0.12

 SUMMARY OF MEASURES OVER ALL ITERATIONS

            - - - - - - - - HUMAN - - - - - - -   - - - - - - EQUIPMENT - - - - - - - -   - - - - - - -- SYSTEM - - - - -
            RELIABILITY AVAILABILITY    MTTR    RELIABILITY AVAILABILITY   MTBF   MTTR   RELIABILITY AVAILABILITY   MTTR
               0.726       0.929        0.69       0.841       0.957       20.7   1.0       0.456       0.999       3.59
```

Figure 4-15. Sample of Run Summary Output Format

Table 4-12 Sensitivity Test Runs

Parameters Varied	Parameter Set–Test Run							Comparison
	1	2	3	4	5	6	7	
Workday length (hours)	18	18	18	12	12	12	18	Average vs. long workday
Primary proficiency								
1. Percent fully qualified	0	0	0	90	90	90	0	High proficiency vs.
2. Percent minimally qualified	10	10	10	10	10	10	10	low proficiency crew
3. Percent unqualified	90	90	90	0	0	0	90	
Secondary proficiency								
1. Percent fully qualified	0	0	0	90	90	90	0	High proficiency vs.
2. Percent minimally qualified	10	10	10	10	10	10	10	low proficiency crew
3. Percent unqualified	90	90	90	0	0	0	90	
Average crew pace	1.0	1.0	1.0	1.0	1.0	1.0	1.25	Average vs. slow crew
Sea state	9	9	0	0	9	0	0	Calm vs. rough seas
Crew size	14	9	9	14	9	9	9	Large vs. small crew

4.5.1 Workday Length and Proficiency Variations. One of the many uses of the model can be phrased symbolically as:

$$A \cap B \simeq C \cap D$$

That is, the occurrence of conditions A and B is approximately equivalent to conditions C and D (in terms of some criterion such as number of successful events). For example, an analyst might be interested in determining whether a crew of lesser proficiency, given more time to work, would perform as well as a crew of greater proficiency given less time. This type of analysis is illustrated in the sensitivity tests reported here. In this aspect of the sensitivity tests, proficiency and workday length were varied concurrently. Table 4-13 presents the workday length-proficiency parameter combinations investigated.

Parameter sets 2 and 3 include a long work day with a crew of low proficiency, while parameter sets 5 and 6 include a short work day with high proficiency. Comparisons between the results from parameter sets 2 and 5 and between parameter sets 3 and 6, accordingly, provide the desired data.

Figures 4-16, 4-17 and 4-18 present the simulation output resulting from the workday length-proficiency variation. The first of these figures indicates an increase in the average physical workload with the shorter workday-higher proficiency. For parameter set 2 in comparison with parameter set 5, as well as for parameter set 3 in comparison with parameter set 6, the increase amounted to better than 25 percent. It is possible that the faster crew has to work harder during the shorter time period allotted to them to complete the day's work and that their greater proficiency does not offset the necessary increase in physical labor. Parameter sets 3 and 6 indicated a much greater degree of physical load than the parameter sets 2 and 5. This result probably, as has been noted earlier, reflects the greater number of events ignored under adverse weather conditions.

Table 4-13. Workday Length and Proficiency Parameter Values for Parameter Sets 2, 3, 5, and 6

Parameters	Parameter Set	
	2 and 3	5 and 6
Workday length (hours)	18	12
Primary proficiency		
Percent fully qualified	0	90
Percent minimally qualified	10	10
Percent unqualified	90	0
Secondary proficiency		
Percent fully qualified	0	90
Percent minimally qualified	10	10
Percent unqualified	90	0
Sea state	2 3 9 0	5 6 9 0
Crew size	9 9	9 9

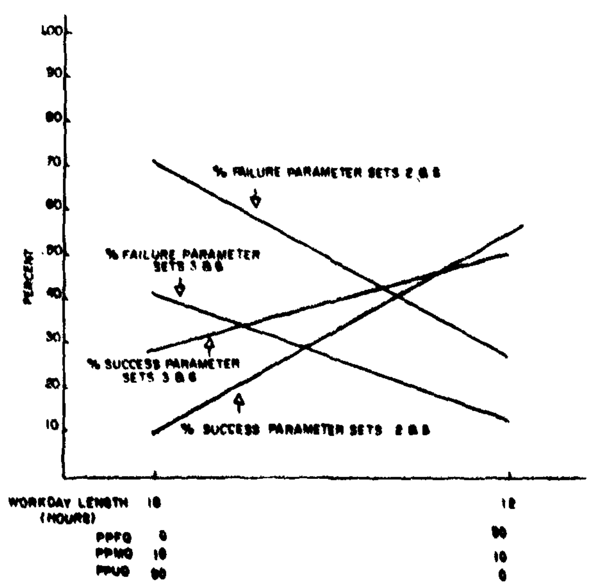

Figure 4 - 16. Event Success and Failure Pecentage as a Function of Workday Length and Proficiency

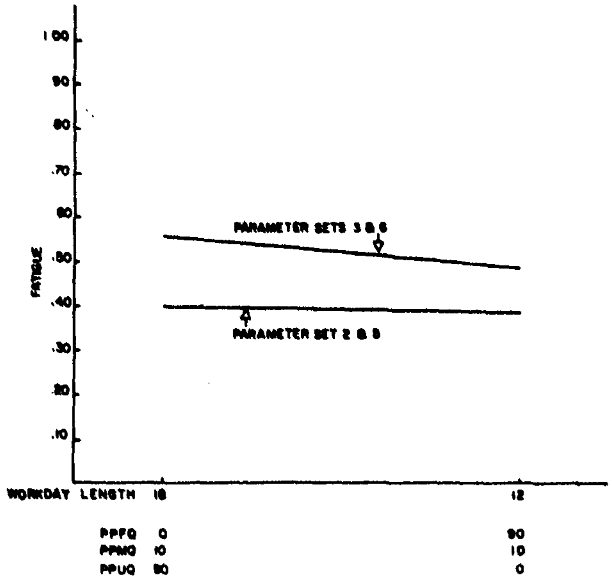

Figure 4-17. Average Fatigue as a Function of Workday Length and Proficiency

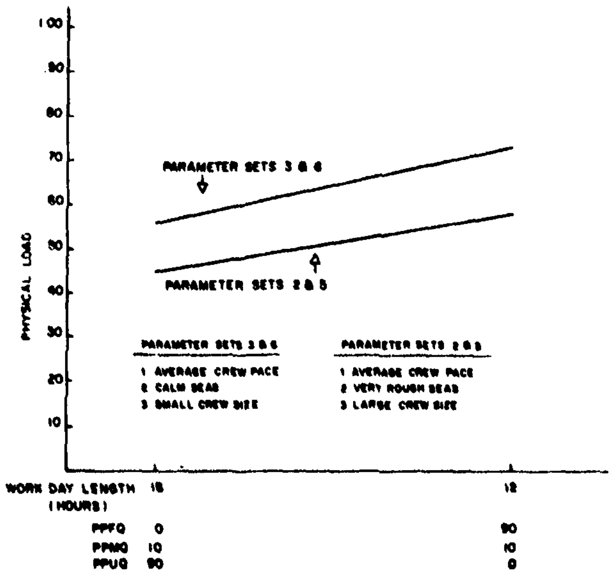

Figure 4-18. Average Physical Load as a Function of Workday Length and Proficiency

Figure 4-16 presents the effects on event success and failure percentages as the result of the workday length-proficiency variation. The percentage of event sucess increased dramatically for the higher proficiency crews. Analogously, percentage of event failure decreased with the increase in proficiency. While the shorter workday would probably have an effect, in and of itself, prior results with an earlier version of this model (Siegel, Wolf, & Cosentino, 1971) suggest that the large variations observed in event success and failure is primarily a function of the variation in proficiency.

Figure 4-17 presents the effect of varying the workday length and proficiency on average end-of-mission fatigue. No effect is indicated for the comparison of parameter sets 2 and 5. For parameter set 3, compared with parameter set 6, a drop of approximately .07 in fatigue was indicated in the higher proficiency-shorter workday combination. Coupled with the results presented in figure 4-18, this suggests that while the average physical load may increase because of the shorter workday, the fatigue level at the end of the day has actually been depressed. The higher average fatigue for parameter sets 3 and 6 is, once again, probably reflective of the large number of events ignored during adverse weather conditions.

4.5.2 Average Crew Pace Variations. Figure 4-19 shows the effect of varying average crew pace on event success and failure for parameter sets 3 and 7. The percentage of events failed increased and the percentage of events successfully completed decreased as the average pace of the simulated crew decreased. The percentage of events failed as a result of a 25 percent decrease in average crew pace (defined as a slow crew) increased approximately 13 percent, and the percentage of events successfully completed approximately 8 percent.

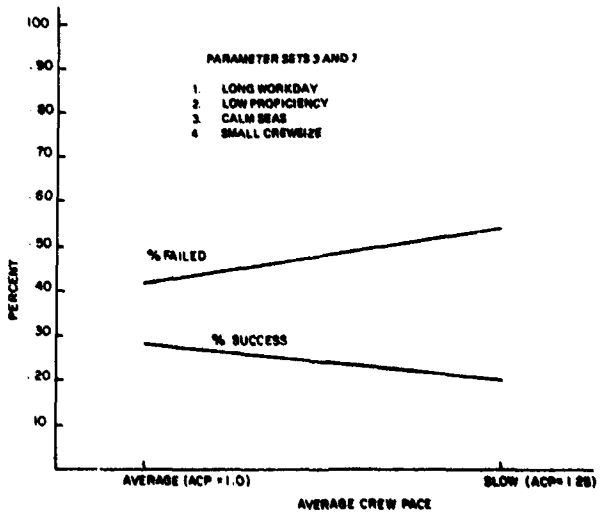

Figure 4-19. Event Success and Failure as a Function of Average Crew Pace

4.5.3 *Variations in Sea State.* The effect of variations in sea state on the model's output is illustrated in a comparison of the simulation results from parameter sets 2 and 3, and parameter sets 5 and 6. Parameter sets 2 and 3 are characterized by: long workdays, low proficiency crews, average crew pace, and small crews. Parameter sets 5 and 6 are characterized by: short workdays, high proficiency crews, average crew pace, and small crews. Parameter sets 2 and 5 have sea state values equal to 9 (rough seas) while parameter sets 3 and 6 have sea state values equal to 0 (calm and glassy) seas.

The effects of variation in the sea state parameter are shown in figures 4-20, 4-21, and 4-22. Figure 4-20 shows the effect of sea state variation on the average failure difference. As anticipated, both parameter sets indicated a larger margin between actual and acceptable performance (the failure difference) for the rough sea state condition. The larger failure differences observed for parameter set 2 as compared with parameter set 3 suggest that, according to the model, a lower proficiency crew working a longer worker day will suffer a significant performance degradation in rough seas and that this degradation is higher than for the short workday, high proficiency crews.

Figure 4-21 presents the effects on the percentage of events successfully completed or failed as a function of difference in sea state. Percentage of failure appears to increase significantly with adverse weather conditions. The effects on percentage of success appear to have been greatest in the comparison of parameter set 2 with parameter set 3. Here, a 14 percent decrease was indicated. The slight increase in percentage of successful events observed for parameter set 5 as compared with parameter set 6 (adverse weather conditions) (4 percent) is consistent with the prior indication of the model that higher proficiency crews working shorter workdays are less affected by the sea state.

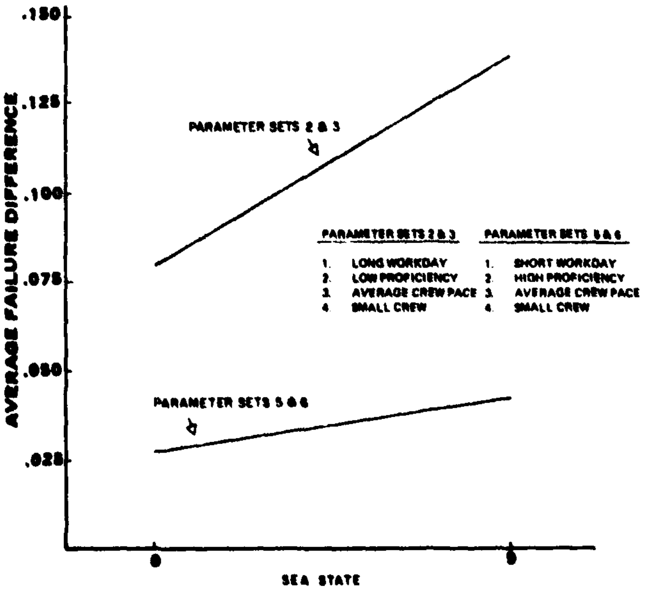

Figure 4-20. Average Failure Difference as a Function of Sea State

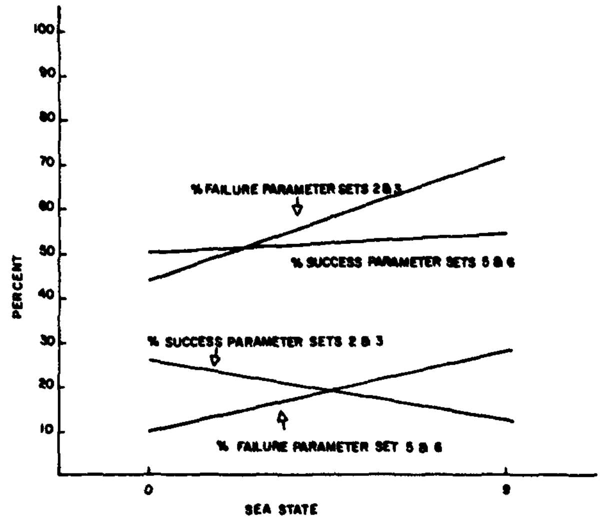

Figure 4-21. Event Success and Failure as a Function of Sea State

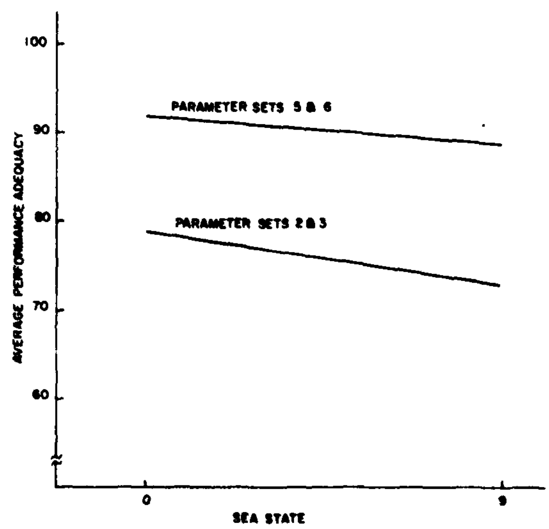

Figure 4-22. Average Performance Adequacy as a Function of Sea State

Figure 4-22 presents the effects of varying sea state on average performance adequacy (APA). Both parameter sets are in agreement. Each indicates a decrease in APA with increasing weather turbulence. Also, as predicted, the better crew (higher proficiency) of parameter sets 5 and 6 demonstrated higher APA. In summary, it appears from the average failure difference, percentage success/failure, and average performance adequacy data that the model yields results which are directionally sensitive in the anticipated direction when the new sea state variable is implemented.

4.5.4 *Crew Size Variations.* The results from parameter set 1 versus 2 and 4 versus 6 represent the effects of variations in crew size on the completion of the events in the simulated day's work. Parameter sets 2 and 6 include crew sizes of 9 men, while parameter sets 1 and 4 are simulations of crews with 14 men. Parameter sets 1 and 2 both involve: long workdays, low proficiency crews, average crew pace, and rough seas. Parameter sets 4 and 6 both include: short workdays, high proficiency crews, average crew pace, and calm seas.

Figures 4-23, 4-24, 4-25, and 4-26 present the effects of crew size variation on selected simulation output. Figure 4-23 indicates an increasing percentage of tasks successfully completed with increasing crew size for both comparisons. The percentage of tasks failed decreased from 71.2 to 65.9 with increasing crew size for parameter sets 1 and 2, while the percentage of tasks failed for parameter sets 4 and 6 remained relatively constant. The effects of crew size variation on task performance accordingly seems to have had its greatest impact on the percentage of tasks successfully completed. Task success percentage increased approximately 10 percent for parameter sets 1 and 2 (less than optimal conditions) and approximately 15 percent for parameter sets 4 and 6 (with more optimal conditions). Increases in the number of events failed with smaller crews seems to be coupled with less than optimal conditions. Large simulated crews were more able to handle the increased workload.

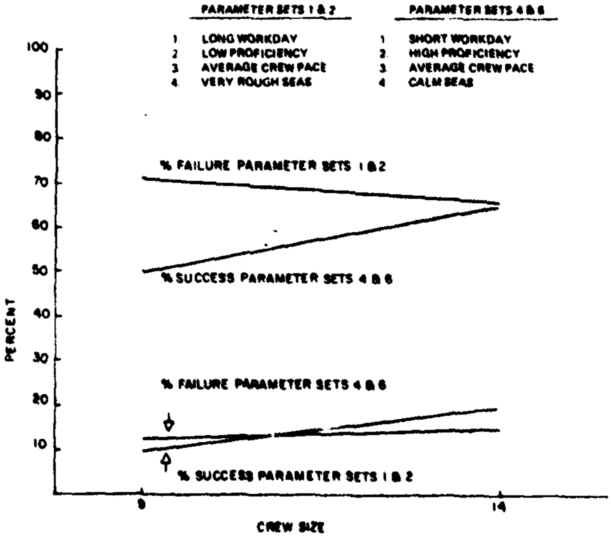

Figure 4-23. Event Success and Failure Percentage as a Function of Crew Size

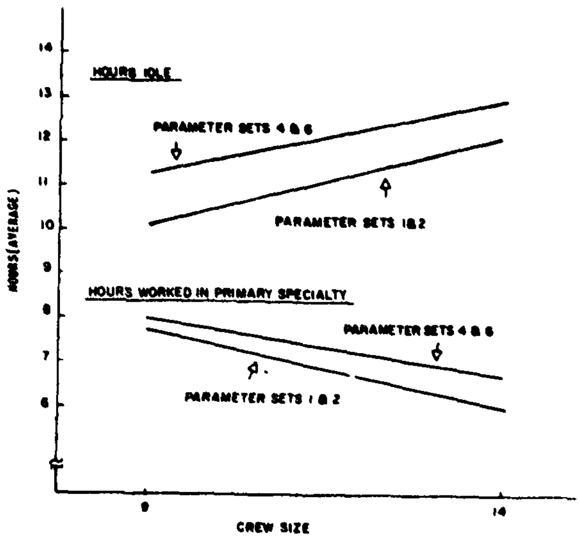

Figure 4-24. Hours (Average) Worked in Primary Specialty and Hours Idle as a Function of Crew Size

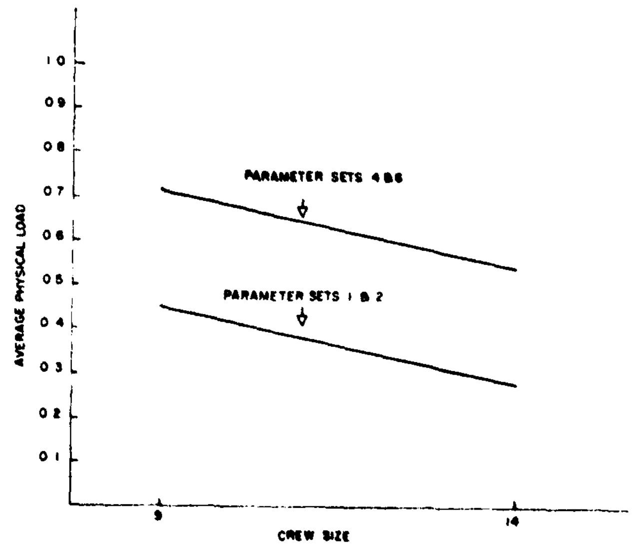

Figure 4-25. Average Physical Load as a Function of Crew Size

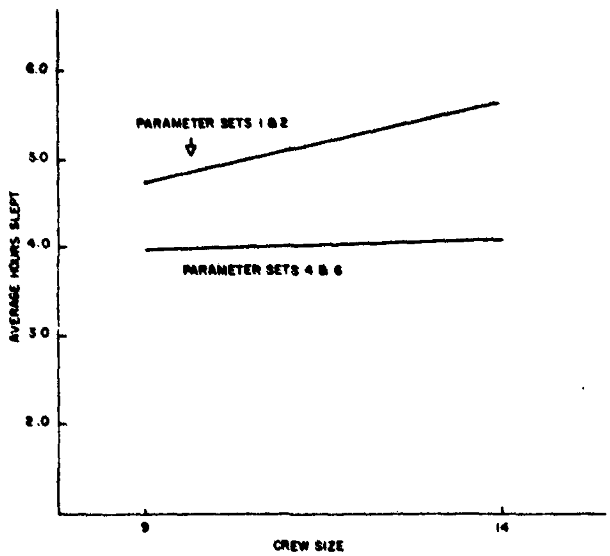

Figure 4-26. Average Hours Slept as a Function of Crew Size

Figure 4-24 indicates that more idle hours and less work by crew members in their primary proficiency accompanies larger crew sizes. Idle time was bout 20 percent greater for parameter set 1 as compared with parameter set 2 and about 10 percent greater for parameter set 4 as compared with parameter set 6. The decrease in time worked in primary specialty is reflective of the general decrease in work time per crew man with increasing crew size.

Figure 4-25 shows the effect of crew size on average physical workload. Increasing the size of the crew results in a simulation output which indicated less physical workload per crew member. The difference in workload between parameter sets 1 and 2 (less than optimal conditions) and parameter sets 4 and 6 (more optimal condtions) reflects the greater number of events attempted (not ignored) and successfully performed (see figure 4-23) by the simulated crew under the more optimal conditions.

The effect of variations in crew size on average hours slept is shown in figure 4-26. With increasing crew size, the average number of hours slept increases for parameter sets 1 and 2, and parameter sets 4 and 6. The effect is marginal for parameter sets 4 and 6. For parameter sets 1 and 2, approximately a 20 percent increase in sleep time available under the more adverse conditions (parameter sets 1 and 2) is a function of more events being ignored.

4.5.5 *Reliability Data.* Human reliability, equipment reliability, and system reliability are provided in the run summary printout, figure 4-15. The reliability data are presented on the last line of the printout which is prepared after completion of all iterations of each run. The reliability data obtained during the tests described in paragraphs 4.5.1 through 4.5.4 are presented in tables 4-14 through 4-16.

Parameter sets 2 and 3 differed only in sea conditions. The sea state in parameter sets 2 and 3 was 9 and 0 respectively. Table 4-14 presents the reliability values for these parameter sets.

*Table 4-14 Overall Reliability Metrics for Parameter Sets 2 and 3 **

Parameter Set	MTBF		MTTR		Availability		System
	Human	Equipment	Human	Equipment	Human	Equipment	Availability
2	0.744	3.384	2.71	20.889	0.215	0.139	0.181
3	2.226	3.367	3.06	21.339	0.421	0.136	0.313

Table 4-15 presents the various reliability metrics comparing the results from parameter sets 3 and 7. These two parameter sets differed only in the assigned average crew pace. Parameter set 7 represented the slower crew. All the metric comparisons, with the exception of the HMTTR comparison, indicate superiority for the faster crew. There was a considerable increase in system availability as the result of manning the simulated system with a faster crew. However, again there is a reversal for the HMTTR comparison. The present thinking relative to this reversal is the same as that discussed for the prior parameter set comparison.

*Table 4-15 Overall Reliability Metrics for Parameter Sets 3 and 7 **

Parameter Set	MTBF		MTTR		Availability		System
	Human	Equipment	Human	Equipment	Human	Equipment	Availability
3	2.226	3.367	3.06	21.339	0.421	0.136	0.313
7	1.649	3.536	2.86	18.130	0.366	0.163	0.283

The effect of the crew size variable with a short workday, high proficiency crews, average crew pace, and calm seas is shown in table 4-16. Parameter set 4 includes a crew of 14 men, while parameter set 6 has a smaller crew (9 men).

*Table 4-16 Overall Reliability Metrics for Parameter Sets 4 and 6 **

Parameter Set	MTBF		MTTR		Availability		System
	Human	Equipment	Human	Equipment	Human	Equipment	Availability
4	5.314	2.829	1.88	18.754	0.739	0.131	0.531
6	6.953	3.157	4.60	15.829	0.602	0.166	0.441

The larger crew indicated a shorter HMTBF, a shorter HMTTR, a higher AVAIL, and a higher system availability. Here, all numerics are in the anticipated direction with a 20.4 percent increase in system availability resulting from the increase in crew size.

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*Since this report was prepared, a number of additions have been incorporated in the model in the calculation of human reliability, MTTR, and availability indices. Corresponding changes have also been incorporated into the calculation of the various system metrics.

5.0 EMPIRICAL MODELS

5.1 Introduction

This section describes several useful empirical models and techniques developed during the Human Reliability Prediction System Program. These techniques can be used to provide useful system planning, design, and test information at several points in the system life cycle. The following tools are described:

- Lognormal distribution models which permit the maintenance parameters of systems to be estimated
- A simple regression model, called the maintenance power model, which relates repair time, man-hours, and repairman experience
- Multiple repairmen prediction models based on a matrix approach
- A flow chart maintainability prediction model which can be used in the multiple repairman case and with PM/FL
- A demonstration procedure which can be used with human reliability

These methods are generally applicable and examples are provided for several system types.

In this section, a new parameter called maintenance power is introduced. Maintenance power is the product of repair time, man-hours, and years of experience of the repairman. The average of this product over all repair actions provides a simple means of relating maintenance man-hours, mean experience, and mean repair time for any system. Maintenance power will be discussed in Section 5.3.2, below.

5.2 Lognormal Distributions of Maintenance Parameters

Maintenance parameters for any electronic equipment can be accurately described by the lognormal distribution. The one exception to this rule is the repair time for large systems. In this case, the full set of data points is frequently bi-modal—modes are identified for distinct sets of repair times of over and under some specific value. For large sonars this value is 10 hours.

The following maintenance parameters are described by a lognormal distribution:

- Repair time
- Man-hours
- Maintenance power
- Men assigned per repair
- Experience assigned per repair

The data in table 5-1 presents maintenance parameters for three typical electrical equipments and one typical mechanical equipment. The distributions of repair time and man-hours are plotted in figures 5-1 and 5-2. These examples are based on field data. Predictive models will be provided below.

Table 5-1. Maintenance Parameter Distributions

Equipment	Maintenance Parameter	Sample Size	Arithmetic Mean	Median	95th Percentile	Std Dev Log X
Large Sonar	Repair Time (≤10 hrs)	237	3.22 hrs	2.30 hrs	8.88 hrs	0.357
	Repair Time (all times)	283	8.55 hrs	3.46 hrs	31.70 hrs	0.585
	Man Hours (≤10 hrs)	237	5.23 hrs	3.29 hrs	16.10 hrs	0.419
	Man Hours (≤all times)	283	19.50 hrs	13.90 hrs	53.90 hrs	0.378
	Maintenance Power	283	68.10 hr-yrs	19.40 hr-yrs	3.25 hr-yrs	0.685
	Men					
	Assigned	283	1.78 men	1.63 men	3.25 men	0.182
	Experience	283	3.80 yrs	3.59 yrs	6.27 yrs	0.148
Nose Landing Gear	Repair Time	82	0.74 hrs	0.70 hrs	1.24 hrs	0.149
	Man Hours	82	1.51 hrs	1.34 hrs	2.96 hrs	0.209
Airborne Digital Comp.	Repair Time	108	1.89 hrs	1.49 hrs	4.65 hrs	0.300
	Man-hours	108	2.72 hrs	1.89 hrs	7.67 hrs	0.369
Airborne Radio Set	Repair Time	108	0.88 hrs	0.72 hrs	2.09 hrs	0.280
	Man-hours	108	1.50 hrs	1.21 hrs	3.58 hrs	0.287
Airborne Radar Set	Repair Time	108	1.69 hrs	1.34 hrs	4.12 hrs	0.297

Some important properties of the lognormal distribution are shown in equations 5-1 through 5-5. If x is truly lognormally distributed, the parameters of the x distribution may be estimated as follows:

- Estimate of median of x = geometric mean of x = Antilog $\left[\left(\sum^{n} \log x\right)/n\right]$ (5-1)

where:

n is the sample size

- Estimate of standard deviation of log x = σ

$$= \sqrt{\frac{1}{1.15}\left[\log(\text{Mean/Median})\right]} \qquad (5\text{-}2)$$

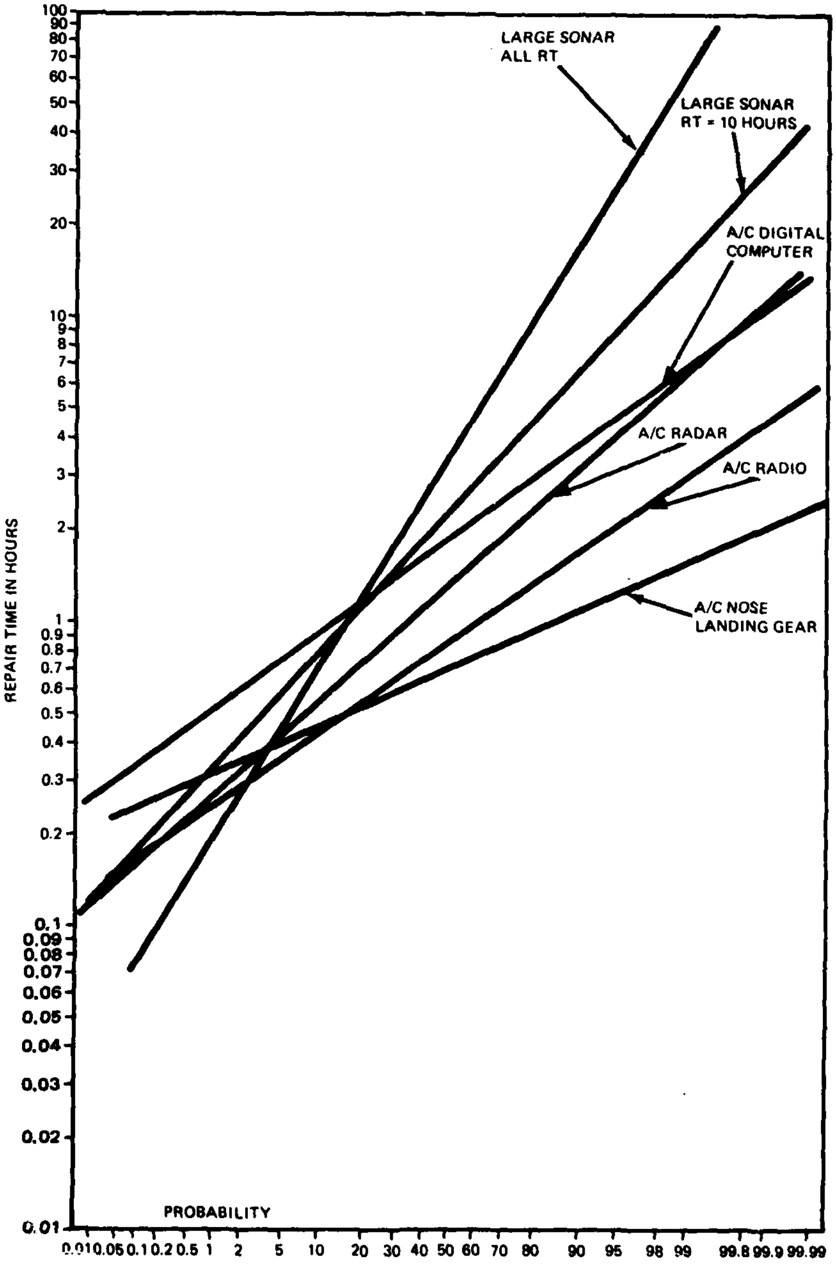

Figure 5-1. Repair Time Distribution for Large Sonar and Aircraft and Electronic and Mechanical Equipment

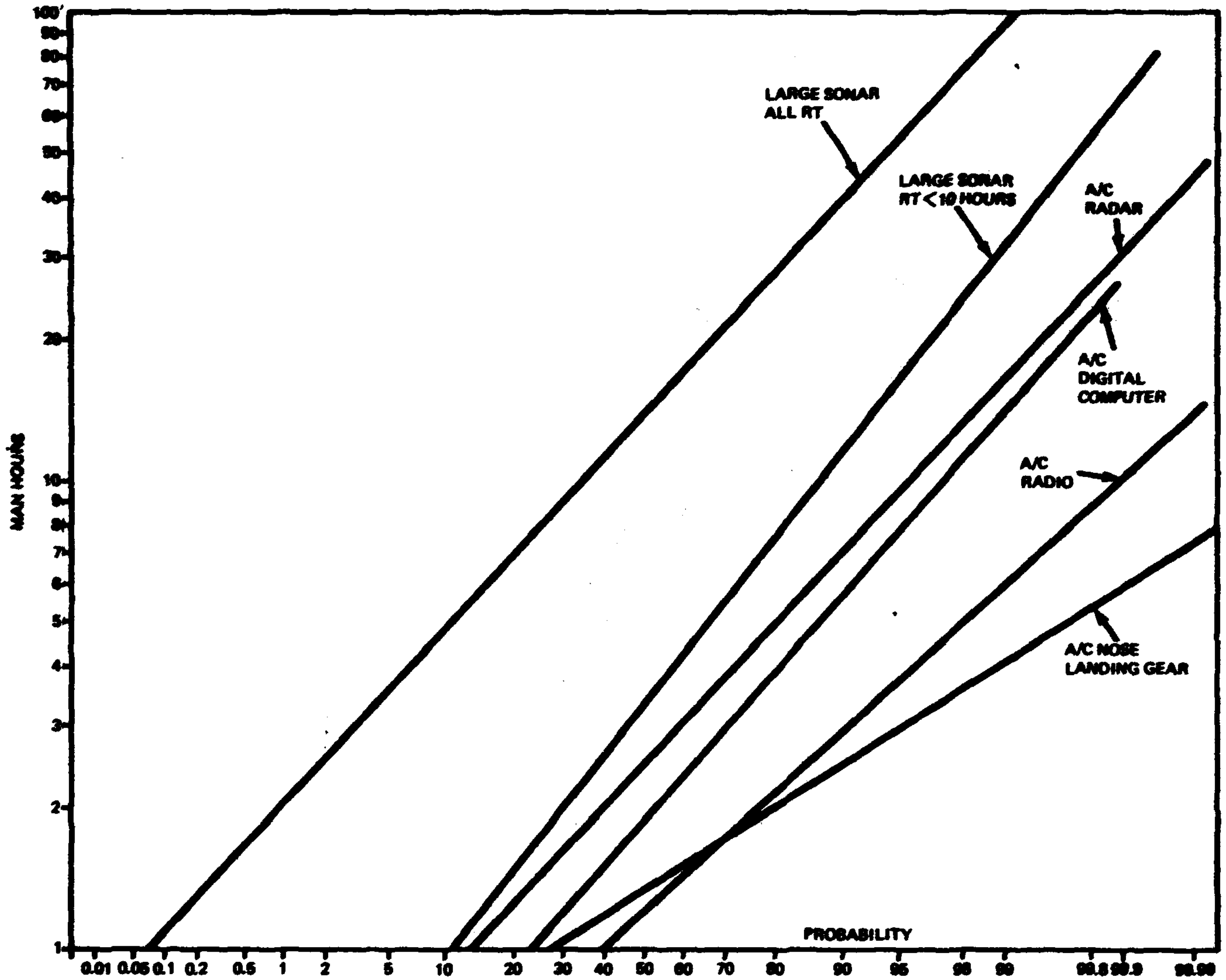

Figure 5-2. Man-Hour Distributions Large Sonar and Aircraft Electronics and Mechanical Equipment

- x_{max} (95th percentile)
  $= \text{(Median)} \exp [1.645\sigma/0.434]$ (5-3)

- Mode of $x = \text{(Median)} \exp [-(\sigma/0.434)^2]$ (5-4)

- $Z = [0.434/\sigma]\ [\ln(x/MED)]$ (5-5)
  Z = standard normal variate with mean equal to zero and variance 1

These equations provide a convenient way to describe the distribution of the key maintenance parameters.

Figure 5-3 is a histogram of repair times for a large sonar. This chart clearly indicates the bi-modal nature of the repair time distribution.

Figure 5-4 presents a plot of average experience vs. repair time and man-hours. A useful finding is that average experience increases with repair time. Above 10 hours, average experience seems to decrease with repair time and man-hours. This finding indicates that more complex repair actions (as indicated by greater repair time) have more experience applied to them. It may, however, indicate the reverse; that more experienced repairmen are actually less proficient and take longer at repairs. More experimental work is needed to resolve this issue. Sufficient funds were not available in the Human Reliability Prediction System Program to obtain the data to draw conclusions about the curves' behavior above 10 hours.

5.3 Simple Lognormal Prediction Models

5.3.1 Simple Maintainability Prediction Techniques. These prediction methods make use of coefficients derived from service-wide maintainability data for specific system types. Predictions can be made for equipments as a function of repair crew size and experience. The prediction models described are designed to be independent of one another.

The models are used to estimate the following important maintainability parameters:

- Maintenance power (man-hours and experience as a function of repair time)
- Distribution of repair time per repair as a function of average repair crew experience
- Distribution of man-hours per repair as a function of average repair crew experience
- Number of repairmen per repair
- Repair crew experience
- Annual man-hours
- Average number of repairmen appearing within each experience category

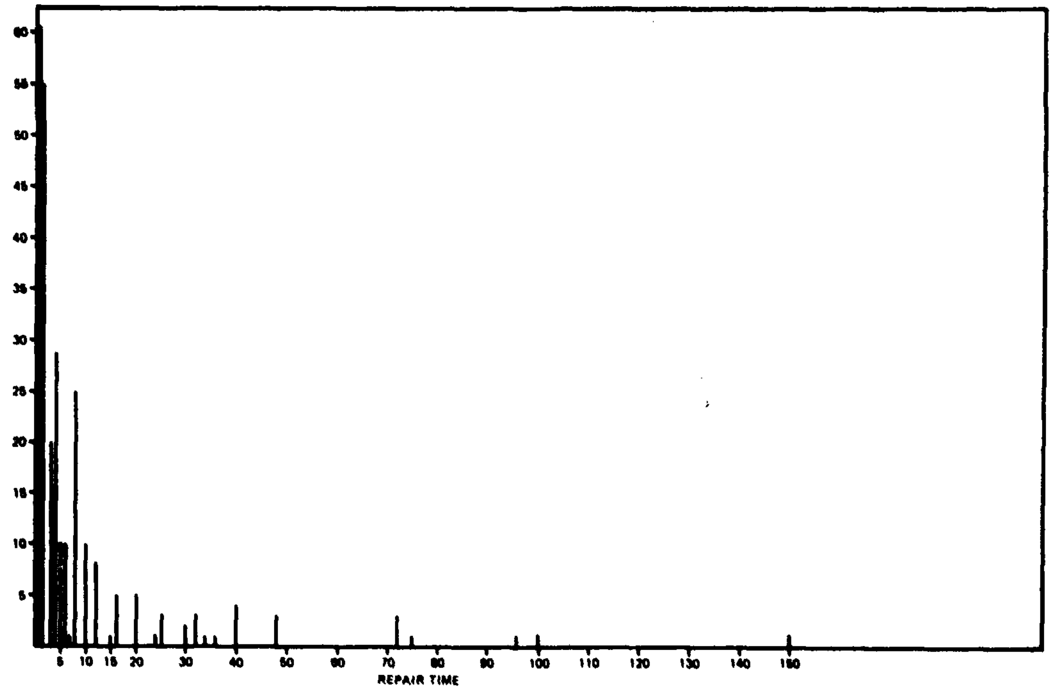

Figure 5-3. Histogram of Large Sonar Repair Time

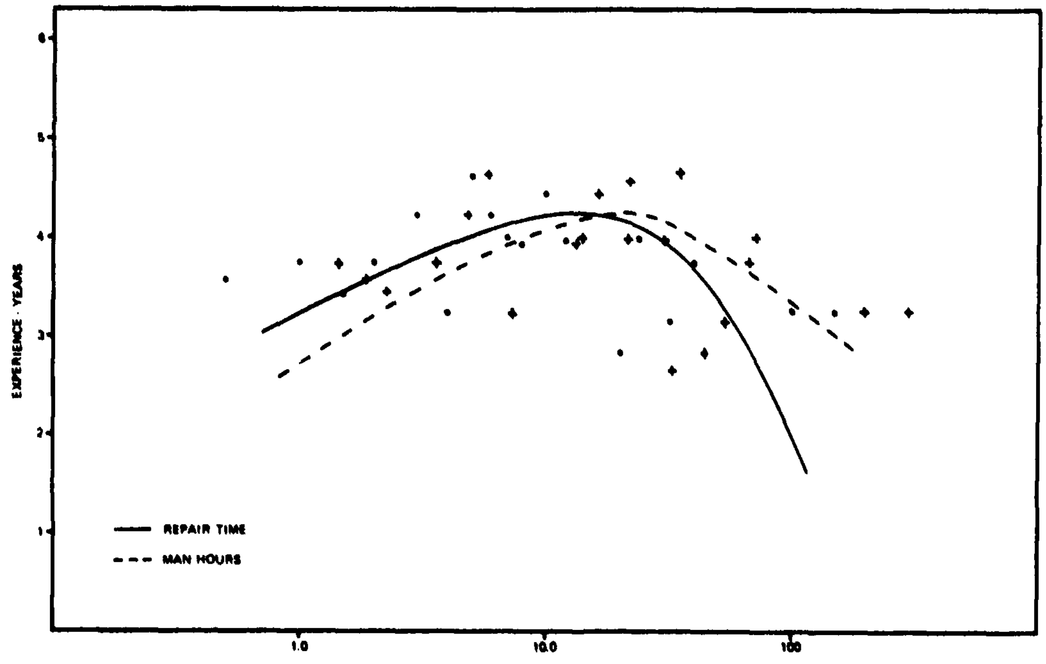

Figure 5-4. Experience vs Repair Time, Large Sonar

The prediction method described makes use of the following items, which can be derived by system type from service data:

- MTTR, geometric MTTR ($MTTR_G$), 95th percentile repair time, standard deviation of the logarithm of repair time (σ_R)
- Mean man-hour (MMH), geometric mean of man-hour (MMH_G), 95th percentile man-hour, standard deviation of the logarithm of man-hour (σ_M)
- Average number of repairmen per repair ($\bar{K}$), geometric mean of number of repairmen per repair ($\bar{K}_G$), 95th percentile number of repairmen per repair, standard deviation of the logarithm of number of men per repair (σ_K)
- Average repair crew experience ($\bar{E}$), geometric mean of experience ($\bar{E}_G$), 95th percentile of experience, standard deviation of the logarithm of experience (σ_E)

Each of the prediction methods is described in the following paragraphs.

5.3.2 *Model for Maintenance Power.* Maintenance power relates mean man-hours, mean repair time (MTTR), and mean experience levels. The maintenance power applied to a repair of any given repair time is equal to the average of the product of the experience levels (years) applied to the repair and the time expended (hours), within each experience level, over all repairs having that repair time.

Statistical analyses of fleet repair data for a large sonar system indicate a very close fit to a straight line equation of the form:

$$MP = \beta R_T = 8R_T \tag{5-6}$$

where

MP = Maintenance power

$\beta = 8$ = The slope of the regression curve

R_T = Repair time

The data indicates that equation 5-6 also describes the relationship between mean values, i.e.:

$$\overline{MP} = 8 \cdot MTTR, \text{ or } MMH\,\bar{E} = 8 \cdot MTTR \tag{5-7}$$

where:

MMH = Mean man-hours

$\bar{E}$ = Average repair crew experience

The second form of equation 5-6 is very useful for early system planning for trade-off studies of maintenance man-hours, technician experience, repair time, availability, and life cycle support cost.

5.3.3 *Repair Time Distribution Prediction.* Using this model, the equipment repair time distribution can be estimated as a function of average repair crew experience. The curve in figure 5-4 gives average repair time as a function of average crew experience. This curve is limited in scope because it was derived from just one large sonar; however, it can be used to illustrate the method. The assumptions underlying the use of this model are as follows:

- Repair time is lognormally distributed.
- The standard deviation of the repair time distribution is not affected by changes in average number of repairmen per repair ($\bar{K}$) and average crew experience ($\bar{E}$). It appears reasonable to assume that the standard deviation is invariant across all systems in the service, for any given system type (σ_R).
- Experience and repair time relationships given in figure 5-4 are known.

The procedure for using the model to predict repair time distribution is demonstrated in example 5-1.

Example 5-1. Repair Time Distribution

Task Description

First, figure 5-4 can be used to estimate the average repair time for a given average experience level. For a hypothetical $\bar{E}$ = 4 years, the average repair time (MTTR) = 4.9 hours.

The derived repair time distribution has σ_R = 0.585 hours. It is assumed that this value does not change. The other characteristics of the repair time distribution (except for σ_R) can be estimated as follows:

Applicable Formulas

$$MTTR_G = \text{Antilog}\,[\log MTTR - 1.15\,\sigma_R^2] \quad (5\text{-}8)$$

$$\text{Maximum Repair Time} = MTTR_G\ \exp\,[\,1.645\,\sigma_R/0.434\,] \quad (5\text{-}9)$$

Procedures

Procedure	Example
1. Substitute MTTR and σ_R into the formula	1. $MTTR_G$ = Antilog [log 4.9 - 1.15 x $(0.585)^2$]
2. Compute $MTTR_G$	2. Antilog [log 4.9 - 1.15 x $(0.585)^2$] = 1.98 hours
3. Using $MTTR_G$, compute Maximum repair time ($MTTR_G$ x exp [1.645 σ_R/0.434])	3. Maximum Repair Time = 1.98 x exp [1.645 x 0.585/0.434] = 1.98 x exp 2.22 = 1.98 x 9.18 = 18.18 hours

5.3.4 *Man-hours Prediction.* The distribution of man-hours per repair can be predicted as a function of average repair crew experience. Again, use is made of a figure such as 5-4. The assumptions for this model are as follows:

- Man-hours are lognormally distributed.
- The standard deviation of the man-hours distribution (σ_M) remains the same and is not affected by $\bar{E}$ and $\bar{K}$ changes. Changes in $\bar{E}$ appear to have very little effect on σ_M; however, $\bar{K}$ changes do have some effect on man-hour characteristics. This is at least true when $\bar{K}$ values remain fairly close to the minimum required value dictated by the inherent maintainability characteristics of the equipment.
- Total man-hours = $\bar{K}$ x (MTTR) x Number of Failures (5-10)

The procedure for using the model to predict the distribution of man-hours per repair is demonstrated in example 5-2.

Example 5-2. Distribution of Man-hours Per Repair

Task Description

Compute the man-hour distribution where σ_M = 0.378 and average technician experience is 4 years.

Applicable Formulas

Median man-hours (geometric mean: MMH_G) = Antilog [log MMH - 1.15 σ_M^2] (5-11)

Maximum man-hours (95th percentile) = MMH_G x exp [1.645 x σ_M/0.434] (5-12)

Procedures

Procedure	Example
1. Estimate mean man-hours (MMH) from graph in figure 5-4.	1. MMH = 8.00 hours
2. Compute median man-hours (geometric mean)	2. MMH_G = Antilog [log 8.00 - 1.15 σ_M^2] = Antilog [log 8.00 - 1.15 x $(0.378)^2$] = 5.48 hours
3. Compute maximum man-hours (95th percentile)	3. Maximum man-hours (95th percentile) = MMH_G x exp [1.645 x σ_M/0.434] = 5.48 x exp [1.645 x 0.378/0.434] = 5.48 x exp [1.433] = 5.48 x 4.19 = 22.96 hours

5.3.5 *Prediction of Number of Repairmen per Repair.* This model is used to predict the median and maximum (95th percentile) number of repairmen per repair based on knowledge of the average number of repairmen per repair ($\bar{K}$). For the sonar fleet data, $\bar{K}$ = 1.78. The assumptions for this model are as follows:

- Number of repairmen per repair is lognormally distributed.
- σ_K is not affected by $\bar{E}$ and $\bar{K}$ changes. Experience with much data indicates that this is valid. $\sigma_K = 0.182$.

The procedure for using the model to predict the number of repairmen per repair is demonstrated in example 5-3.

Example 5-3. Repairmen per Repair

Task Description

Given $\sigma_K = 0.182$ compute repairmen per repair.

Applicable Formulas

Median repairmen per repair ($\bar{K}_G$):

$$\bar{K}_G = \text{Antilog}\ [\log \bar{K} - 1.15\ \sigma_K^2] \quad (5\text{-}13)$$

$$\text{Maximum Repairmen per Repair} = \bar{K}_G \times \exp\ [1.645 \times \sigma_M/0.434] \quad (5\text{-}14)$$

Procedures

Procedure	Example
1. Compute $\bar{K}_G$	1. $\bar{K}_G$ = Antilog [log $\bar{K}$ - 1.15 σ_k^2] = Antilog [log 1.78 - 1.15 x $(0.182)^2$] = 1.63 Repairmen
2. Compute maximum repairmen per repair (MRR)	2. MRR = $\bar{K}_G$ x exp [1.645 x σ_M/0.9434] = 1.63 x exp [1.645 x (0.182)/0.434] = 3.25 Repairmen

5.3.6 *Prediction of Repair Crew Experience.* This model is used to predict the median and maximum experience level per repair. This model is based on the following assumptions:

- Repair crew experience is lognormally distributed.

- The standard deviation of the experience distribution (σ_E) remains constant and is not affected by $\bar{E}$ and $\bar{K}$ changes. For the purposes of simplicity in prediction, it is not unreasonable to make this assumption, $\sigma_E = 0.148$, *from the* available data.

The procedure *for using the model* to predict experience level per repair is demonstrated in example 5-4.

Example 5-4 Experience Level Per Repair

Task Description

The prediction is made using the average experience level per repair ($\bar{E}$) assumed as the input to the illustrative examples in this section. $\bar{E} = 4$ years. The model permits the median experience per repair and maximum experience per repair to be estimated.

Applicable Formulas

Median experience per repair ($\bar{E}_G$):

$$\bar{E}_G = \text{Antilog}\,[\,\log \bar{E} - 1.15\,\sigma_E^2\,] \tag{5-15}$$

$$\text{Maximum experience per repair} = \bar{E}_G \times \exp\,[\,1.645\,\sigma_E/0.434\,] \tag{5-16}$$

Procedures

1. Compute $\bar{E}_G$

   1. $\bar{E}_G = \text{Antilog}\,[\,\log \bar{E} - 1.15\sigma_E^2\,]$
      $= \text{Antilog}\,[\,\log 4 - 1.15 \times (0.148)^2\,]$
      $= 3.77$ years

2. Compute maximum experience per repair

   2. Maximum experience per repair
      $= \bar{E}_G \times \exp\,[\,1.645\,\sigma_E/0.434\,]$
      $= 3.77 \times \exp\,[\,1.645 \times (0.148)/0.434\,]$
      $= 6.61$ years

5.3.7 Prediction of Annual Man-hours and Average Number of Repairmen Appearing at Each Experience Level. These parameters are very useful to logistics system planners. They provide data for manning level and life cycle cost estimates. In order to perform these calculations, it is assumed that:

- Repair crew experience and man-hour distributions have been calculated.
- Accumulated Man-hours at Experience Level E = Mean Man-hours/Man/Repair x Men Appearing at Experience Level E.

The procedure for using the model to predict annual man-hours and average number of repairmen at each experience level is demonstrated in example 5-5.

Example 5-6 Annual Man-Hours and Average Number of Repairmen in Each Experience Level

Task Description

Predict the experience distribution and plot the results as in figure 5-5. For the example, E (median) = 3.77 years and E (95th percentile) = 6.61 years.

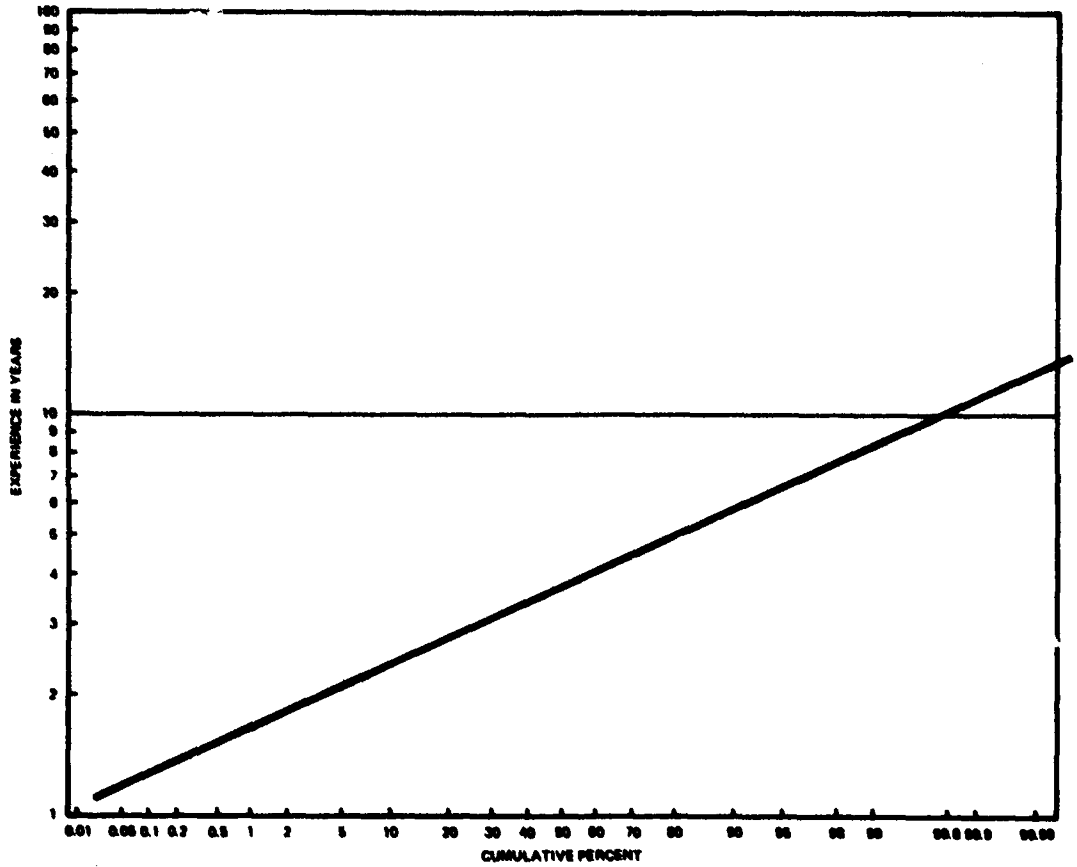

Figure 5-5. Typical Experience Cumulative Distribution

Given data:

- Average repairmen/repair ($\overline{K}$) = 1.78
- Annual operating time = 5,000 hours
- MTBF = 500 hours

Applicable Formulas

Average Annual Number of Repairmen

$$= (\text{Average Repairmen/Repair}) \times \left(\frac{\text{Annual Operating Time}}{\text{MTBF}}\right) \qquad (5\text{-}17)$$

$$\text{Total annual man-hours} = \text{Mean man-hours} \times \left(\frac{\text{Annual Operating Time}}{\text{MTBF}}\right) \qquad (5\text{-}18)$$

Apportioned Repairmen = Percent in Experience Interval
x Average Total Repairmen (5-19)

Apportioned Annual Man-hours in Experience Interval
= Percent in Experience Interval x Annual Man-hours (5-20)

Procedures

Procedure	Example
1. List the ship's repair crew experience. Show range of experiences, cumulative percent and percent of each interval from the lognormal plot given in figure 5-5.	1. See table 5-2
2. Compute average total annual number of repairmen in repair actions using formula 5-17.	2. Average annual number of repairmen $= (\text{Average Repairmen/Repair}) \times \left(\frac{\text{Annual Operating Time}}{\text{MTBF}}\right)$ $= 1.78 \times \frac{5000}{500}$ = 17.8 repairmen in repair actions
3. Estimate the expected total accumulated annual man-hours using formula 5-18.	3. Total annual man-hours $= \text{Mean man-hours} \times \left(\frac{\text{Annual Operating Time}}{\text{MTBF}}\right)$ $= 8.0 \times \frac{5000}{500} = 80$ hours

4. Use the experience distribution results (table 5-2) to compute the average number of repairmen in each experience level category (formula 5-19) and the associated number of man-hours (formula 5-20).

4. Computed for the 3 year experience interval

   a. Apportioned repairmen

      = percent in experience interval

      x Average total repairmen

      = 0.42 x 17.8

      = 7.48 repairmen

   b. Apportioned annual man-hours in experience interval

      = percent in experience interval

      x Annual man-hours

      = 0.42 x 80.00

      = 33.6 man-hours

Table 5-2. Experience Distribution Summary

Experience level (years)	3	4	6	8	10
Range of Experience (years)	0-3.5	3.5-5	5-7	7-9	9 or greater
Accumulative Percent (at upper band of experience range)	42%	87%	96.5%	99.5%	100%
Percent for each Interval	42%	45%	9.5%	3%	0.5%

5.3.8 Trade-off Relationships. The relationships presented above can be used for simple but efficient trade-off analyses between repair time, man-hours, experience levels, failure rates, spares stockage levels, availability, and costs.

Basic relationships presented in this section are:

$$MMH \cdot \bar{E} = \beta\, MTTR \quad (5\text{-}21)$$

$$MTTR = f(\bar{E}) \quad (5\text{-}22)$$

$$MMH = g(\bar{E}) \quad (5\text{-}23)$$

$$\text{Total man-hours} = \bar{K} \cdot MTTR \times \text{No. of failures} \quad (5\text{-}24)$$

$\bar{K}$ = Some known value

To these can be added the following relationship from classical reliability theory:

The reliability of the ith subsystem is $R_i(t) = e^{-\lambda_i t}$ (5-25)

where:

λ = failure rate of ith subsystem

System reliability calculations are adequately covered in many standard texts.

The subsystem availability is:

$$A_i(t) = \frac{1}{1 + \left(\frac{\lambda_i}{\mu_i}\right)} \tag{5-26}$$

where:

μ_i = repair rate of ith subsystem

The system availability is:

$$A_S(t) = A_1 \cdot A_2 \cdots A_N \tag{5-27}$$

The probability of running out of spares in mission of time T fc. each module type # i is:

$$P(\text{spares}) = \frac{e^{-\lambda_i T}(\lambda_i T)^S}{S!} \leq 0.1 \tag{5-28}$$

where:

S = number of spares

Simple equations for life cycle support costs or models such as the LOR model (MIL-STD-1390A) can be used to relate costs to design and support system parameters. These models and the above equations can be used to perform trade-offs.

5.4 Multiple Repairman Maintainability Prediction Model - The Matrix Model

5.4.1 *Introduction.* At the present time, the conventional maintainability prediction and demonstration procedures described in MIL-HDBK-472 and MIL-STD-471A are only associated with single man repair tasks. Also, differences in training and experience between the repairmen are not adequately accounted for in these prediction models. This section introduces a mathematical model for maintainability prediction that takes into consideration the effects of utilizing multiple repairmen, as well as considering differences in training and experience.

In the single-man repair situation, the man-hours and active repair (or elapsed) time are always identical; therefore, the maintainability characteristics of an equipment can be adequately expressed in terms o its repair time characteristics. In the situation of complex systems, repairs usually require the services of more than one repairman. Consequently, system maintainability characteristics can no longer be adequately defined by repair time characteristics alone; constraints on other characteristics (such as man-hours and number of repairmen) must also be defined.

The fact that repair time, man-hours, and the number of repairmen can all be approximated by lognormal distributions permits the assumption that multiple repairman actions may be shown to consist of a simple combination of single repairman actions using a matrix model. The matrix method of predicting MTTR's and MMH's is described in the next paragraph.

5.4.2. ***Matrix Calculations.*** The matrix method of maintainability prediction is best described by a series of illustrations for the parameter types of interest.

5.4.2.1 ***Calculation of $MTTR_S$.*** The arithmetic system MTTR, $MTTR_S$, is calculated by the following relationship:

$$MTTR_S = \sum_{i=1}^{K} \alpha_i \overline{M}_{AX_i} = \text{The mean time to repair the system} \qquad (5\text{-}29)$$

where:

α_i = Probability that i repairmen are assigned.

i = Denotes the number of repairmen associated with a repair; i ranges from 1 through K.

$$\text{Note } \sum_{i=1}^{K} \alpha_i = 1. \qquad (5\text{-}30)$$

$\overline{M}_{AX_i} = C_{X_i}\overline{M}_i$ = Human factor adjusted average system repair time for i men repair team.

C_{X_i} = Repair time human adjustment factor for i men repair team. This is a team-work factor reflecting gain in efficiency due to team-work. $0 < C_{X_i} < 1$.

Typical values of C_{X_i} for a large sonar system are:

$C_{X_1} = 1$, This is obvious for a 1-man team.

$C_{X_2} = 0.306$ for 2-man teams.

$C_{X_3} = 0.244$ for 3-man teams.

The equation for $MTTR_S$ can be rewritten as:

$$MTTR_S = \sum_{i=1}^{K} \underline{\alpha}_i \overline{M}_{AXi} = \underline{\alpha}^T M_{A\underline{X}} 1 = \alpha^T A_X \underline{M1} \qquad (5\text{-}31)$$

where:

$\underline{a}^T$ = The transpose of a_i

I = Unit matrix

$$\Delta X = \begin{bmatrix} C_{X_1} & 0 & 0 \\ 0 & C_{X_2} & 0 \\ 0 & 0 & C_{X_3} \end{bmatrix}$$

The parameters or a typical large sonar problem are:

a_1 = Probability of 1-man per repair = 0.1

a_2 = Probability of 2-men per repair = 0.7

a_3 = Probability of 3-men per repair = 0.2

$\overline{M}1$ = Mean repair time of 1-man repairs = 4.1 hours

Therefore, the $MTTR_s$ is obtained as follows:

$$a = \begin{bmatrix} 0.1 \\ 0.7 \\ 0.2 \end{bmatrix}$$

$$a^T = [0.1, 0.7, 0.2]$$

$$\Delta X = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0.306 & 0 \\ 0 & 0 & 0.244 \end{bmatrix}$$

$$\overline{M} = 4.1$$

$$\perp = \begin{bmatrix} 1 \\ 2 \\ 3 \end{bmatrix}, \quad \perp = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$$

therefore:

$$MTTR_S = [0.1, 0.7, 0.2] \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0.306 & 0 \\ 0 & 0 & 0.244 \end{bmatrix} [4.1] \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$$
$$= 1.49 \text{ hours}$$

5.4.2.2 ***Calculation of Mean Man-hours per System Repair (MMH_S).*** The mean vlaue of man-hours per system repair is given by:

$$MMH_S = \sum_{i=1}^{K} \alpha_i \, \overline{MH}_{AYi} = \alpha^T \overline{MH}_{AY} 1 \qquad (5\text{-}33)$$

where:

$$\overline{MH}_{AY}M = A_Y \overline{MH} \qquad (5\text{-}34)$$

$$A_Y = \begin{bmatrix} C_{Y_1} & 0 & 0 \\ 0 & C_{Y_2} & 0 \\ 0 & 0 & C_{Y_3} \end{bmatrix} \qquad (5\text{-}35)$$

C_{Y_i} = Human factor adjustment factor on man-hours. $0 < C_Y \leq 1$

Typical values for a large sonar system are:

$$C_{Y_1} = 1$$
$$C_{Y_2} = 0.526$$
$$C_{Y_3} = 0.451$$
$$\overline{MH} = [MH_1] \qquad (5\text{-}36)$$

Consider the large sonar of the previous example. If all parameters remain the same and the mean man-hours for a single repairman situation, $\overline{MH}_1$ = 4.1 hours, the mean system man-hours can be calculated from

$$MMH_S = [0.1, 0.7, 0.2] \begin{bmatrix} 1.0 & 0 & 0 \\ 0 & 0.526 & 0 \\ 0 & 0 & 0.451 \end{bmatrix} [4.1] \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$$
$$= 2.29 \text{ hours}$$

5.5 Flow Chart Maintainability Prediction

5.5.1 *Introduction.* At the present time, Procedure II in MIL-HDBK-472 is probably the most popular maintainability prediction procedure. However, because of its reliance on table 2-2 of that handbook the procedure can only be used for preliminary maintainability prediction studies,* since this table is rather insensitive to hardware design changes and totally insensitive to maintenance procedure improvements. Therefore, the Flow Diagram Maintainability Prediction Method is presented in order to estimate the maintenance times for a given system more realistically. This method improves maintainability prediction accuracy, helps to standarize troubleshooting procedures, reduce the expected number of maintenance steps, and establish a troubleshooting priority that is roughly consistent with circuit criticality. The method can be used for maintainability growth monitoring and man-hour prediction. Because the flow diagram can simulate most of the maintenance tasks, it is a highly desirable prediction method for contracts that require maintainability demonstration.

Another important characteristic of the method is that it can be used to predict arithmetic mean repair time and mean man-hours independent of the distribution of repair time. In addition, it can be used for analog and digital systems.

5.5.2 *Basic Concepts.* The following steps are used when applying the flow chart model.

- Conduct a Level of Repair analysis to determine the system's modular and replaceable part structure.
- Conduct a Failure Mode and Effects Analysis to determine the symptoms resulting from the failure of each replaceable item or module.
- Evaluate the results of the first two steps and construct a troubleshooting flow diagram which defines the logic and physical actions of the repair process. Rules which should be followed are:
  - Whenever feasible, each test point indication should eliminate from suspicion roughly half of the potentially faulty circuits. This rule is consistent with decision theory concepts using failure rates as the weighting factors.
  - Troubleshooting actions should consist of a logical deduction from visual analysis of selected signal outputs, the BITE/PMFL readings obtained while manipulating front panel controls and limited groups of modules/replaceable items. In some cases, testing by simple replacement may be necessary.

The flow chart is constructed under the assumption that only one independent circuit fault can occur in the receiver at a time, because the probability of two simultaneous independent faults is extremely low.

* Localization, isolation, alignment, and checkout times in MIL-HDBK-472, table 2-2, are based on the average maintenance test times of a wide variety of naval electronic equipments of vintage lots prior to 1965.

Determine the time required for each analytic and physical step in the flow chart:

- Test equipment setup time (t_s).
- Overall system diagnosis time (t_{od}) (This is the time required to determine the starting point of the analysis from system level indications.)
- Module isolation/localization time (t_{ILM}) (This is the average time required to trace through the logic paths to determine if a module is faulted. If several paths lead to the same module, they must all be included in the analysis.)
- Replaceable item isolation/localization time (t_{ILR}); same definition as for modules.
- Module replacement and check time (t_M) (This is the time to check the test points, jacks, and visual indicators on the suspected module, replace the module, and check its functioning. For some modules, alignment time is needed.)
- Replaceable item checkout time includes time to remove, replace, and check replaceable items.

Specific time elements can be derived from tables 2-2 to 2-5 in MIL-HDBK-472 and from the best judgment of the maintainability engineer, after consultation with design and maintenance personnel.

The MTTR is computed from the following equation:

$$MTTR = t_s + t_{od} + \frac{\Sigma \lambda_i \, Rp_i}{\lambda_t} \quad (5\text{-}37)$$

where:

t_s = test equipment setup time

t_{od} = overall system diagnosis time

λ_i = failure rate of the i'th module or repairable/replaceable item

λ_t = $\Sigma \lambda i$

Rp_i = $t_{il} + t_m$ = the time required to isolate, check, repair/replace, and check the i'th module/part. This is derived by tracing through each path in the flow diagram.

The geometric mean of repair time (or median) is computed from:

$$MTTR_G = \text{Antilog}\left[\log t_s + \log t_{od} + \frac{\Sigma(\lambda i \log Rp_i)}{\lambda_T}\right] \quad (5\text{-}38)$$

The standard deviation can be computed from:

$$\sigma = \sqrt{\frac{1}{1.15}\left(\log \frac{MTTR}{MTTR_G}\right)} \tag{5-39}$$

The 95th percentile can be computed from:

$$R_T(95) = MTTR_G \exp\left[1.645\ \sigma/0.434 \right] \tag{5-40}$$

The procedure described above can be extended to the multiple repairman case quite simply, by assuming that certain groups of tasks can be performed in parallel. Each man works on a specific group of logical steps and physical activities, either completely in parallel or alternating. This allows the case of repairmen working at different locations (i.e., CIC and equipment room) to be evaluated. The case where several technicians must work together on heavy mechanical gear can also be considered.

5.5.3 *Examples.* The flow chart method can be illustrated by means of a simple example for a digital system which includes a power converter, two module groups, and a rack assembly. Organizational maintenance is performed by means of module replacement. Some visual fault locating is provided by means of an indicator lamp on the front face of critical modules. However, most fault locating must be accomplished by measuring the signals at a large number of test points which are brought out to the front face of the modules.

The flow chart procedure is illustrated as follows:

1. Figure 5-6 defines the overall troubleshooting procedure. If the system contained a sophosticated PM/FL, many logical steps in the analysis of the module groups would be zero, and the block "Overall System Diagnosis" might be slightly larger than three men.

2. Figure 5-7 illustrates the logical and physical steps used to isolate faulty power supply modules. The mean repair time calculation for the power converter is summarized below:

   - The process illustrated in figure 5-7 and step 2 is repeated for each module group and the rack assembly.

   - The MTTR calculation is summarized as follows:

Module Group at End of Line	λ_i	$\lambda_i R_{Pi}$
Power Converter	2.9637836	8.112905
Module Group I	28.481625	329.996866
Module Group II	11.226419	126.5552210
Rack Assembly	0.841026	50.46156
Totals	43.512853	515.126552

$$MTTR = 2 \text{ min} + 3 \text{ min} + \frac{515.126552}{43.512853}$$

$$= 16.84 \text{ min}$$

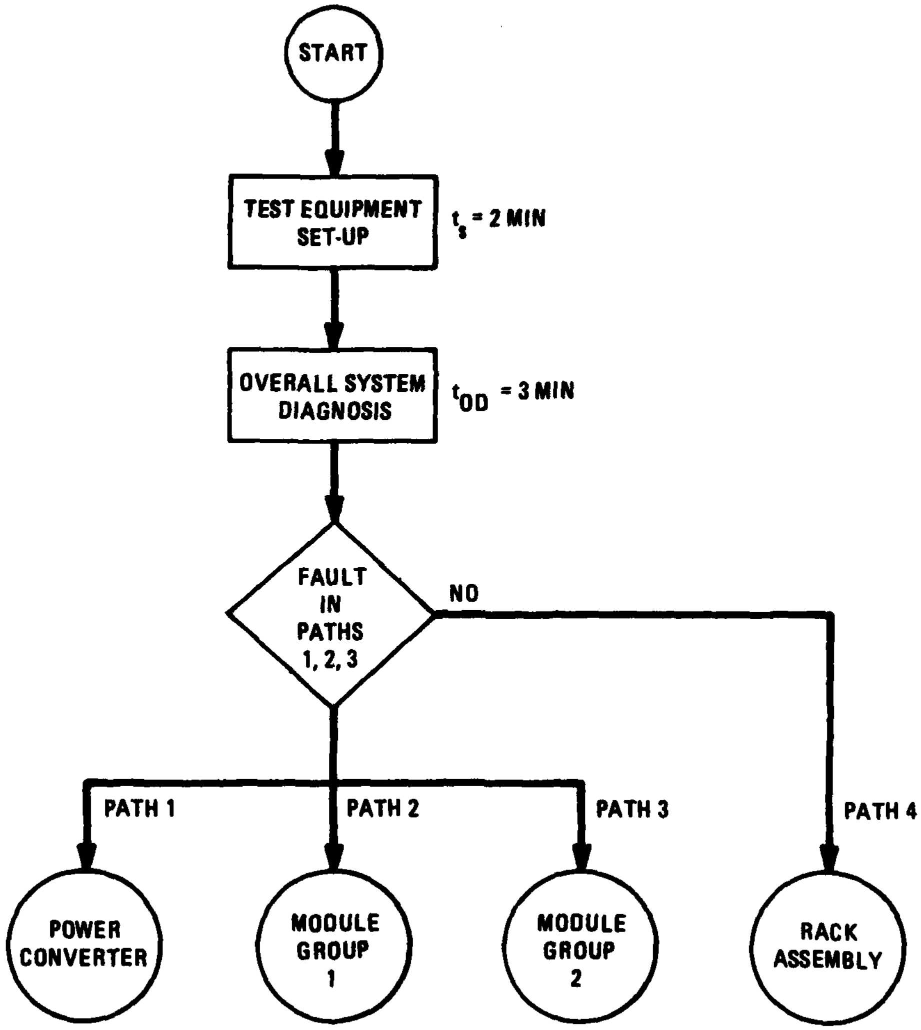

Figure 5-6. Digital System Maintenance Flow Chart

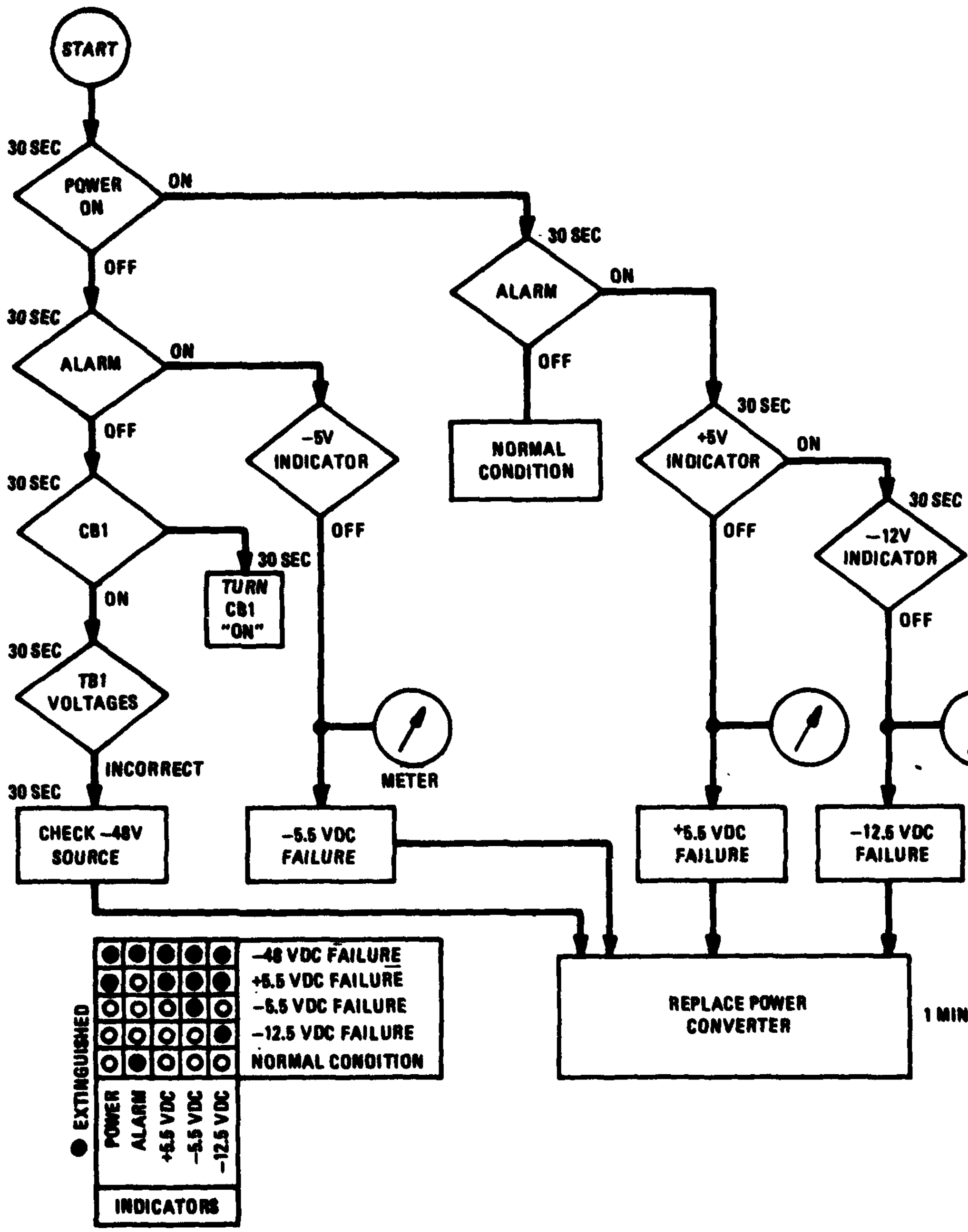

Figure 5-7. Power Converter Maintenance Path

5.5.4 *Impact of PM/FL System on Flow Chart Maintainability Prediction.* If the system is equipped with a PM/FL system, the maintenance times associated with many of the diamond shaped decision blocks in the flow diagram will be reduced to zero. The system checkout time will also be reduced accordingly. When the troubleshooting and checkout times become negligible, the repair time characteristics, being dominated by the assembly/disassembly times, will generally become a normal distribution. However, when a PM/FL is not fully effective, the influence of troubleshooting times will remain substantial and the lognormal principle could still be applied for maintainability prediction.

At the present time, a common practice in PM/FL design is to enable the system to localize faults to a small number of modules; consequently, manual troubleshooting is still commonly used. In such cases, the system flow diagram shown may be broken down into a number of discrete flow diagrams, each being associated with a group of potentially faulty modules designated by the PM/FL system; consequently, the maintainability prediction approach will remain the same as that described in the previous paragraphs.

In case a group of faulty modules cannot be troubleshot by logical deduction of circuit functions, a common practice is to try the random spare module substitution method. In such a case, maintenance flow diagram may be abbreviated and the following mathematical model may be applied.

Given the following input parameters:

n = Number of modules in the group

λ_i = Failure rate of i^{th} module

i = The order of module substitution, that is:

Module 1 is substituted with a spare first. If it is not the faulty module, Module 2 will be substituted with its spare, etc., i has a range from 1 through n.

t_i = The estimated total repair time for the i^{th} module including all the wrong module substitution and checkout times.

The following may be calculated:

$$\lambda_i / \sum_{i=1}^{n} \lambda_i = \text{The probability the } i^{th} \text{ module is defective} \qquad (5\text{-}41)$$

$$\text{Expected Group Repair Time} = \sum_{i=1}^{n} t_i \lambda_i / \sum_{i=1}^{n} \lambda_i \qquad (5\text{-}42)$$

If $\boxed{k}$ is the average module removal time plus spare insertion and checkout time, the total repair time for 2, 3, . . . n modules is given by:

$$
\begin{aligned}
t_2 &= t_1 + \boxed{k} \\
t_3 &= t_1 + 2\boxed{k} \\
t_n &= t_1 + (n-1)\boxed{k}
\end{aligned}
\tag{5-43}
$$

If $\lambda_1 = \lambda_2 = \lambda_n$, the equation for Expected Group Repair Times becomes:

$$\sum_{i=1}^{n} t_i/n = t_1 + \frac{(n-1)}{2}\boxed{k} \tag{5-44}$$

If $t_1 = \boxed{k}$ + Cover Removal & Installation Time .

$$\text{Expected Group Repair Time} = \frac{(n+1)}{2}\boxed{K} + \text{Cover} \tag{5-45}$$

5.6 Maintenance Parameter Demonstration

5.6.1 *Introduction.* Since repair time, man-hours, and number of men per repair are the inherent maintainability characteristics of an equipment, they should be specified in contract requirements and tested in maintainability demonstration. Repair times, man-hours, maintenance power, repairman experience, and men per repair are lognormally distributed. Consequently, the demonstration plan described in the following paragraphs can be used to test each of these maintainability parameters.

5.6.2 *Demonstration Procedure Model 1 – The Median.* This demonstration tests the acceptability of the median of a lognormal variate (x) when the requirement is specified in terms of both a specified median (M_o) and a maximum median (M_1). The basic test model is derived from Test Plan 4 of MIL-STD-471A (sample size = 20). The hypothesis testing model is shown in figure 5-8.

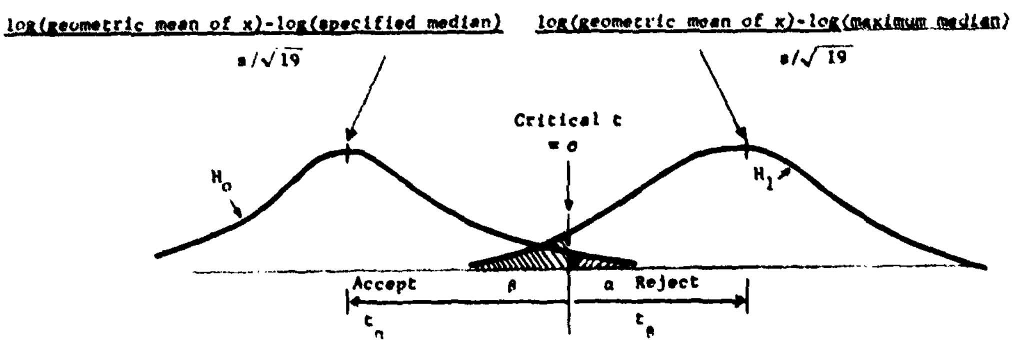

Figure 5-8. Hypothesis Testing of the Median

The null hypothesis is

$$H_0:\ M \leq M_0 \quad = \quad \text{specified median} \tag{5-46}$$

The alternate hypothesis is

$$H_1:\ M \geq M_1$$

This accept-reject criteria requires that both of the following be true:

$$\left[\frac{\log(\text{geometric mean of } x) - \log(\text{specified median})}{s}\sqrt{19} \leq -t_\alpha\right] \tag{5-47}$$

indicates H_0 is true with $\geq (1-\alpha)$ probability

$$\left[\frac{\log(\text{geometric mean of } x) - \log(\text{maximum median})}{s}\sqrt{19} \geq -t_\beta\right] \tag{5-48}$$

indicates H_1 is true with $\leq \beta$ probability

where:

α = producer's risk that the system will be rejected even if $M \leq M_0$

β = consumer's risk that the system will be accepted even if $M \geq M_1$

M_0 = Specified median of x

M_1 = Specified maximum median of x

Geometric Mean of x = Antilog $\sum_{i=1}^{n} (\log x_i)/n$

s = Estimate of the standard deviation of logarithm of x

$$= \sqrt{\frac{\sum_{i=1}^{n} (\log x_i)^2 - n\left[\log(\text{geometric mean of } x)\right]^2}{n-1}}$$

t_α, t_β = values of student's t distribution at percentage points α, β, i.e.

$$t_\alpha = 1.729 \text{ for } \alpha = 0.1$$

$$t_\beta = 1.328 \text{ for } \beta = 0.2$$

n = sample size = 20

5.6.3 *Demonstration Procedure Model 2 – The Mean.* This demonstration model tests the acceptability of the mean of a lognormal variate (x) when the requirement is stated in terms of a minimum acceptable or specified mean (μ_o) and a specified maximum mean (μ_1). The basic model is the same as that outlined in MIL-STD-471A Test Plan 1A. The detailed hypothesis testing model is shown in figure 5-9.

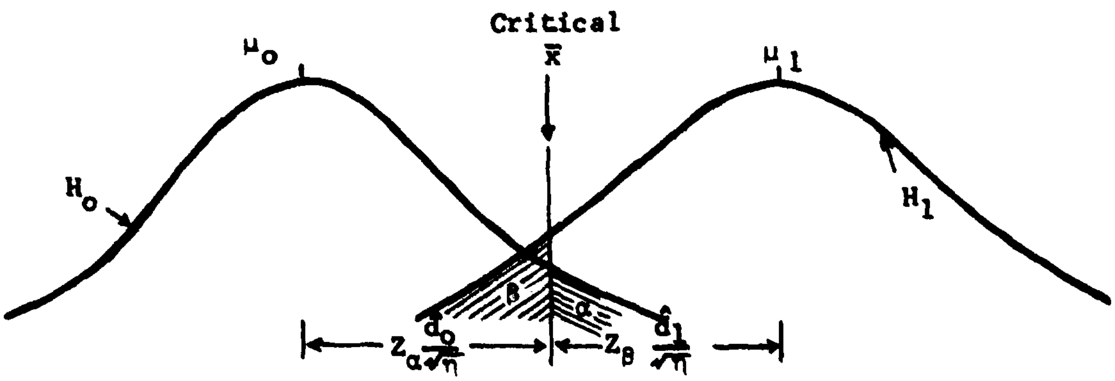

Figure 5-9. Hypothesis Testing of the Mean

This method assumes σ^2 (the variance of lnX) is unchanged regardless of whether the null hypothesis H_o or alternate hypothesis H_1 is true; however, because of the assumption that x is lognormally distributed, the variances of the maintenance times d_o^2 and d_1^2 are not equal.

The null hypothesis is

$$H_o: \ \mu \leq \mu_o = \text{ specified mean of x} \tag{5-50}$$

The alternate hypothesis is

$$H_1: \ \mu \geq \mu_1 = \text{ specified mean of x} \tag{5-51}$$

The accept-reject rules are

Accept H_o if $\bar{X} \leq \mu_o + Z_\alpha \frac{d_o}{n}$ and $\bar{X} \leq \mu_1 - Z_\beta \frac{d_1}{n}$

Reject H_o otherwise.

where:

$$d_o = \mu_o \sqrt{\exp \sigma^2 - 1}$$

$$d_o = \mu_o \sqrt{\exp \sigma^2 - 1}$$

$$\hat{\sigma}^2 = \sum_{i=1}^{n} \frac{\ln x_i - \left[\ln (\text{geometric mean of } x)\right]^2}{n-1}$$

$$X = \sum_{i=1}^{n} X_i/n$$

n = the sample size which should be at least 30 or larger

6.0 ALLOCATION OF MAN-MACHINE RELIABILITY

6.1 Introduction

This chapter presents an allocation methodology which is based on conventional optimization techniques and permits equipment acquisition and human operator/maintainer constraints to be readily addressed. The methodology incorporates the human as a part of the system by combining the human reliability results described in the previous chapters with conventional hardware reliability models. A simple example is provided to illustrate application of the methodology.

6.2 Basic Concepts

The central concept of the man-machine allocation is the "Operational Reliability" concept (Ref 37).

The Operational Reliability concept extends conventional reliability concepts. It considers the human as an integral part of the system and considers the fact that systems are frequently developed for more than one mission. Operational Reliability is defined as the probability of successful operation of a total man-machine system over all mission employments of that system. The man-machine system consists of the system hardware, software, interfaces and personnel. In quantitative terms, Operational Reliability is written as:

$$R_{op} = \sum_i p_i r_i \qquad (6\text{-}1)$$

where the p_i's represent the probabilities that certain missions will be employed and the r_i's are the mission reliabilities. The expressions selected for the mission reliabilities will include the human element. The Operational Reliability concept can be combined with cost and personnel constraints and the human reliability models to permit the optimal allocation of reliability to man-machine system elements.

6.3 Formulation of the Allocation Method

Mission reliability and operational readiness are the best parameters for optimization because of their wide applicability. Other parameters that could be selected are mean-time-to-failure and mean-time-to-repair, but these should only be used as a descriptor of mission reliability and operational readiness. Availability may be used in place of operational readiness depending on the planned use of the system. Bazovski (Ref. 4) provides an excellent discussion for distinguishing between readiness and availability. The parameters selected provide a direct link between high level effectiveness requirements and component oriented design parameters such as MTBF, MTTR, and numbers and skill level of personnel.

To apply mission reliability and operational readiness to the allocation, first identify critical functions and their reliability and maintainability design parameters and use these to write expressions for the mission reliability and operational readiness of the man-machine system. The mission reliability expression plays a dual role since it provides an input to the expression for operational reliability and to the mission reliability constraint. One mission reliability constraint equation and one operational readiness equation must be written for each mission.

Cost and personnel constraints must also be constructed. Personnel can be specified many ways. For purposes of the allocation, the most convenient way is to specify numbers of men at discrete skill level. This method allows clear definition of the effect of the human component on system mission reliability and operational readiness. For example, crew size and skill level can be related to MTTR, which also impacts operational readiness and mission reliability (where repair is a factor). Numbers and skill levels are critical parameters in the human reliability models.

Acquisition cost, support cost, and life cycle cost can all be used as constraints. One important consideration is that optimizing against one type of cost constraint does not necessarily optimize against the others. Regardless of the cost constraint selected, the cost of the system must be defined in terms of human and hardware contributions and in terms of the basic design parameters to be allocated.

The allocation problem can be written as an optimization problem. The parameters to be optimized would be, for example, function MTBF, function MTTR, and numbers and skill levels of personnel. The problem formulation would be:

$$\text{Maximize } R_{op} = \sum_i p_i r_i \tag{6-2}$$

subject to

$$\text{Mission reliability} = R_m > \overline{R}_m$$

$$\text{Operational readiness} = P_{or} > \overline{X}_m$$

$$\text{Personnel} = N < \overline{N}$$

$$\text{Cost} = \overline{C} < C$$

Constraints are written as vectors to represent the fact that there will be one set of constraint equations for each mission. Equation 6-2 leads directly to the standard form for optimization problems. Additional equations which can be used in the optimization process were given as equations 5-21 through 5-28.

Conventional methods can be employed to solve the allocation problem for the design parameters which are used as the basic set of variables. Dynamic programming is the most straightforward method of solution. Other methods can also be used.

The presentation of the formulation of the allocation problem has been quite general. Any number of practical situations in both the commercial and military fields can be represented according to the choice of requirements and constraints. To show how one might apply this general formulation to a practical situation, a simple example has been provided in the following section. The example also shows how the mathematics becomes rather complicated even when a simple system is analyzed.

6.4 Sample Allocation Problem

In this section the formulation of a specific allocation problem will be illustrated. A very simple system configuration, shown in figure 6-1, will be used. Here, the λ's and μ's correspond to failure rates and repair rates for their respective system components. At this point, no assumption is made about their mathematical characteristics.

For simplicity, the simple system has no human operator functions, but does have human maintainer functions, defined by repair rates. The maintainers are of two skill levels, represented by E_1 and E_2.

The system will be employed on only two missions, A and B, with mission probabilities p_A and p_B, and mission times T_A and T_B. Each mission requires a mission reliability, r_A and r_B, and an operational reliability, X_A, and X_B. Regardless of mission, the number of maintenance men cannot exceed N and the cost of the entire system, men and machines, cannot exceed C.

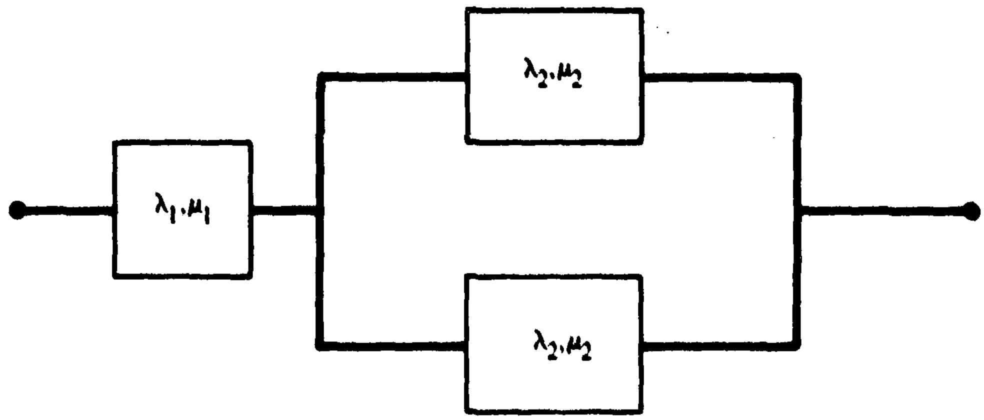

Figure 6-1. System Configuration for Sample Problem

For our "first order" approach, the repair rate is considered a constant, and the probability of correct repair is represented by

$$P\mu(t) = 1 - e^{-\mu t} \quad (6\text{-}3)$$

Note that according to chapter 5, μ, mean time to repair, is a function of personnel number and skill level so that $\mu = \mu(n_1, n_2, \mu_o)$, where n_1 and n_2 are numbers of maintainers at each skill level and μ_o is the equipment configuration impact. $P_\mu(t)$, then, is actually, $P(n_1, n_2, \mu_o; t)$. The maintenance power model can be manipulated to show that

$$MTTR = MMH \cdot E_{ave} \cdot \frac{1}{\beta} \quad (6\text{-}4)$$

where, for the example

$$E_{ave} = \text{average skill level} = \frac{n_1 E_1 + n_2 E_2}{n_1 + n_2}$$

is derived from assignment probabilities and equipment repair characteristics as they impact repairs by given numbers of men as described in the discussion of basic concepts.

The reliability function for the system is given by:

$$R(\mathbf{Z}, t) = R(\lambda_1, \lambda_2, n_1, n_2, \mu_0, t) = \frac{s_1 e^{s_2 t} - s_2 e^{s_1 t}}{s_1 - s_2} \times e^{-\lambda_1 t} \qquad (6\text{-}5)$$

where

$$s_1 = -\tfrac{1}{2}\left[3(\lambda_2 + \mu_2) - \sqrt{\lambda_2^2 + 6\lambda_2\mu_2 + \mu_2^2}\right]$$

$$s_2 = -\tfrac{1}{2}\left[3(\lambda_2 + \mu_2) + \sqrt{\lambda_2^2 + 6\lambda_2\mu_2 + \mu_2^2}\right]$$

To write operational readiness, Bazovsky's expression must be modified to account for preventive maintenance.

The following equation provides the appropriate expression for operational readiness.

$$P_{OR}(\mathbf{Z},t) = P_{OR}(\lambda_1, \lambda_2, n_1, n_2, \mu_0; t) = R(\mathbf{Z};t) + \sum_i Q_i(\mathbf{Z};t)P_i(t_r < t_c) + \sum_i F_i(\mathbf{Z},t)P_i(t_r < t_c) \qquad (6\text{-}6)$$

where the latter summation is the preventive maintenance analog to the corrective maintenance summation of Bazovsky. For the example under consideration:

$$P_{OR}(\mathbf{Z};t) = R(\mathbf{Z};t) + Q_1(\mathbf{Z};t)P(\mu_1, t_c) + 2Q_2(\mathbf{Z};t)P(\mu_2, T_c) + F_1(\mathbf{Z};t)P_i(t_c) + 2F_2(t)P_2(t_c) \qquad (6\text{-}7)$$

From equations 6-5 and 6-7, the operational reliability expression, the mission reliability and the operational readiness constraints can be written as:

$$R_{OP} = P_A R(\mathbf{Z};T_A) + P_B R(\mathbf{Z};T_B) \qquad (6\text{-}8)$$

$$e^{-\lambda_1 T_A} \; \frac{s_1 e^{s_2 T_A} - s_2 e^{s_1 T_A}}{s_1 - s_2} > r_A$$

$$e^{-\lambda_1 T_B} \; \frac{s_1 e^{s_2 T_B} - s_2 e^{s_1 T_B}}{s_1 - s_2} > r_B$$

$$R(Z;T_A) + Q_1(Z;T_A)P(\mu_1,t_c) + 2Q_2(Z;T_A)P(\mu_2,t_c)$$

$$+ F_1(Z;T_A)P_1(t_c) + 2F_2(Z;T_A)P_2(t_c) > X_A$$

$$R(Z;T_B) + Q_1(Z;T_B)P(\mu_1,t_c) + 2Q_2(Z;T_B)P(\mu_2,t_c)$$

$$+ F_1(Z;T_B)P_1(t_c) + 2F_2(Z;T_B)P_2(t_c) > X_B$$

The personnel constraint is easier to write as follows:

$$n_1 + n_2 < N \tag{6-9}$$

The cost model can be written a variety of ways, depending on the choice of cost model. For this simplified example, costs are modeled by:

$$C\ \text{hardware} = K/\lambda \tag{6-10}$$

$$C\ \text{personnel} = kn$$

For the example, the total system cost constraint is given by:

$$K_o\left(\frac{1}{\lambda_1}, \frac{1}{\lambda_2}\right) + K_1n_1 + K_2n_2 < C \tag{6-11}$$

Even with the simplifications made, a dynamic programming solution is required.

Simulation models can also be used to allocate man-machine reliability. The outputs of the human reliability prediction simulations described in chapters 3 and 4 can be combined with dynamic programming algorithms for optimum allocation (figure 6-2). These programs provide output of sufficient detail to permit suboptimization.

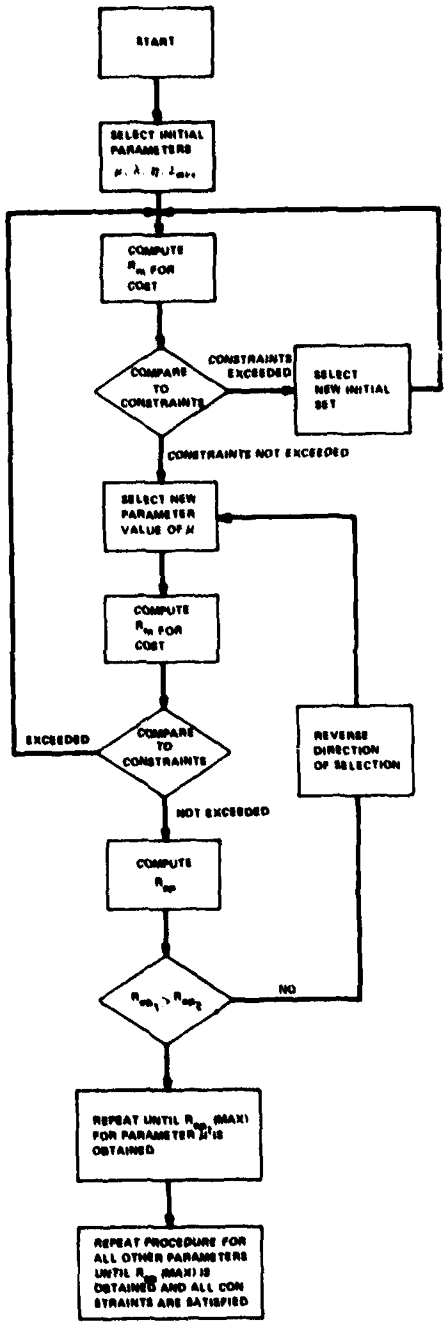

Figure 6-2. Simplified Dynamic Programming Procedures

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APPENDIX A VARIABLES AND FORTRAN CODES

This appendix lists and defines the variables in the digital simulation program as follows:

- Appendix A1 - variables in the program for the 1-2 man digital simulation model
- Appendix A2 - principal subscript variables and FORTRAN codes for the 4-20 man digital simulation model

APPENDIX A1: LIST OF VARIABLES FOR PREPROCESSOR

This appendix lists and defines the variables in the digital simulation program for the 1-2 technician model.

Variable List for Preprocessor
(Subroutine RAM)

FORTRAN IV Program Name	Description
AID(I,J)	Average increase or decrease in $\overline{P}_{ij}$ for individual task elements.
ICE(I,J)	It's close enough indicator, adjustment to within .01 of the theoretically perfect combination of probabilities was considered sufficient.
IOK	Counter to determine when all probabilities have been adjusted to acceptable values.
JAG(I,J)	Technician type of each crewman.
NG(JAG,J)	Number of task element success probability before manipulation.
PG(JAG,J)	Cummulative probability of success of task elements within each job activity group.
INR(JAG,J)	The NG^{th} root of SPOG.
IP(JAG,J)	The total potential increase for all task elements in each job activity group.
SPOG(JOG,JOT)	The overall success probability of each technician type on each job activity group.

Variable List for Main Routine

FORTRAN IV Program Name	Description	Symbol Used in Reports
A1	Average time at which a task was completed by operator 1, taken over a run (summary run output).	
A2	Average time at which a task was completed by operator 2, taken over a run (summary run output).	
A3	Frequency distribution-average stress over a run at the beginning of each task for operator 1, (summary run output).	
A4	Frequency distribution-average stress over a run at the beginning of each task for operator 2, (summary run output).	
ADDSTR	Stress additive.	A_{ij}
AFS	Average final stress over N iterations (summary run output).	
ALPH	Joint task indicator (detailed output).	
APS	Average peak stress over N iterations (summary run output).	
ASTS	Average starting total stress per task, per operator.	
ATMU	Average time to complete each task and all preceding tasks.	
ATU	Average time used over N iterations (summary run output).	
ATW	Average waiting time over N iterations (summary run output).	
AUGSTR	Augmented stress= total stress.	S_{ij}
AVD	Average final goal aspiration difference over N iterations.	

Variable List for Main Routine (cont.)

AVGCOH	Frequency distribution-average cohesiveness for each task over a run (summary run output).	
AVGTM	Average task execution time (input)	$\bar{t}_{ij}$
AVGTMD	Time deviation-average sigma (input).	$\bar{\sigma}_{ij}$
BLK	Temporary storage block for the calculation of a success probability modifier.	
BLOCK	Average of ISUMF and ISUMI.	
COHES	Cohesiveness.	C_{ij}
COHLAS	Last cohesiveness value (summary iteration output).	
CONVER	Conversion constants for time scaling.	
CWAIT	Total time spent for cyclic wait during an iteration (summary iteration output).	
DT	Difference (time used-time available).	
ESS	Essentiality indicator (input).	E_{ij}
FO2	Constant= 0.02.	
GOF	Total number of task failures during iteration.	
GOSF	Total number of all tasks during an iteration.	
HEAD	Designator for title of plotted results.	
I	Task number.	i
IASTS	Count of the number of tasks per iteration.	
IAVG	Count of successful tasks per iteration.	
ICALI	Indicator for entry/reentry to input subroutine.	
ICHNG	Number of iterations before output type is changed (input).	

Variable List for Main Routine (cont.)

IFREQ	Frequency distribution-number of items that each task was ignored (summary run output).	
IFREQF	Frequency distribution-number of times that each indicated task was failed (summary run output).	
IFREQL	Frequency distribution-number of times that each task was the last task completed (summary run output).	
IGNORE	Flag for essential/non essential tasks.	
IN	Standard system input tape number= 5.	
IND1	Idicator for number of times random number generator is called before run starts (input).	
IND2	Type of output for first ICHNG iterations (input).	
IND3	Subtracted from IND2 after ICHNG iterations. Controls level of detail of output for first ICHNG iterations (input).	
IND4	Always equal 1 (input) (could be deleted).	
IND5	Unit code for time units (input).	
IO	Standard system output magnetic tape number= 6.	
IP	Other operator= partner	j'
IPKF	Frequency distribution-number of times peak stress occurred on specific task (summary run output).	
IPREC	Task precedence (input).	d_{ij}
IPRECS	Temporary for IPREC.	
IQ	Temporary for NXTS.	
IRET	Indicator for goal aspiration program segment entry.	
ISTRS	Task number on which peak stress occurred (summary iteration output).	

Variable List for Main Routine (cont.)

ISUC	Indicator for task success or failure.	
ISUMI	Total number of tasks ignored over a run (summary run output).	
ISUMF	Total number of task failures over a run (summary run output).	
ITASK	Current task number.	
ITER	Iteration number (iteration summary output).	
ITMUP	Iterim variable in the calculation of the staring time for cyclic task.	
J	Operator number.	j
JP	Other operator designator.	
JT	Temporary location for JP,J.	
K	Operator number (iteration summary output).	
NINPC	Number of task data cards, also the sum of the last task number for each operator (input).	
NMAX	Number of tasks for the operator who possess the greater number of tasks.	
NOTSK	Average number of all tasks per iteration over N iterations.	
NRUN	Run number.	
NTASK	Number of tasks assigned to each operator.	
NUMCOH	Number of tasks in which cohesiveness is calculated.	
NUMIT	Number of iterations per run (input).	N
NUMRUN	Number of runs (input).	
NUMSUC	Number of iteration successes per run.	
NUMTRL	Trial number.	
NXTF	Number of next task if current task is failed (input).	$(i,j)_f$

Variable List for Main Routine (cont.)

NXTJ	Next task indicator for current operator on special jump task.	
NXTJP	Next task indicator for partner on special jump task.	
NXTS	Number of next task if current task is successful (input).	$(i,j)_s$
OT	Indicator of task success (blank), failure (F), or ignore (I).	
OV	Overrun/underrun indicator (iteration summary output).	
PERF	Performance= number of success/total number of tasks.	
PI	Constant= 3.141...	
PRBSUC	Average probability of task success, probability that next task will be NXTS.	$\bar{p}_{ij}$
PRD	Period for cyclic tasks (input parameter).	P_j
PRSUC	Percentage of iteration successes in a run.	
PV1	Three dimensional array for storage of dependent variable plots.	
PV2	Three dimensional array for storage of independent variable plots.	
RDEV	Random number normally distributed with mean= 0, and sigma= 1.	
SFI	Success/failure indicator.	
SPEED	Individuality factor (input parameter).	F_j
STRM	Stress threshold (input parameter).	M_j
STR	Stress, also final stress at end of iteration.	s_{ij}
STRS	Peak stress of an iteration (summary iteration output).	

Variable List for Main Routine (cont.)

SUMCOH	Sum of cohesiveness values over an iteration.	
SUMTF	Total time of all failed tasks over a run (run summary output).	
SWAIT	Average cyclic wait over N iterations (summary run output).	
T1	Temporary for total time remaining.	
T2	Temporary for time remaining for essential tasks.	
T3	Temporary for time remaining for non-essential tasks.	
TEMP	Larger of two operators' time available.	
TIME	Task execution time.	t_{ij}
TITLE	First card of input.	
TMAVA	Time available for mission (input parameter).	T_j
TMBEG	Temporary for the time of beginning a task.	
TMLE	Sum of time remaining for essential tasks.	T^E_{ij}
TMLN	Sum of time remaining for non-essential tasks.	T^N_{ij}
TMU	Total time used for all prior tasks for current operator	T^U_{ij}
TOTALT	Total time used for iteration (summary iteration output).	
TOTTMI	Task waiting time (detail output).	
TOTTMS	Total waiting time (summary iteration ouput).	
TSUMTF	Frequency distribution-total time spent in failed tasks (summary run output), also average of above over a run).	
TWOPI	2 · PI= 6.28...	
XRAND	Random number uniformly distributed in interval 0 - 1.	

APPENDIX A2 - PRINCIPAL SUBSCRIPT VARIABLES AND FORTRAN CODES

Principle Subscript Variables

	FORTRAN Variable	Maximum Value	FORTRAN Maximum Value
Event number*	IE	200	IEMAX
Event type	IETYP	30	—
Day number	ND	30	NDMAX
Consumable	L	10	LMAX
Spare parts consumable	L1	10	LMAX1
Type of personnel	NT	10	NTMAX
Next event alternative	IA	3	—
Command eschelon (Also called level or rank)	ICE	4	—
1. officer			
2. senior p.o.			
3. junior p.o.			
4. unrated			
Type of emergency	K	10	KMAX
Equipment	IQ	30	IQMAX
Crew member	M	20	IC
Consumable threshold (units)	ITS1	10	ITMAX1
Consumable threshold set (units/time)	ITS	10	ITSMAX
Sea state	IS	9	ISMAX
Group member	IG	20	NB
Duty shifts	NDS	6	NDSMAX
Equipment type	JET	4	JETMAX
1. mechanical			
2. electromechanical			
3. electrical			
4. electronic			
Data change value	IEDCV	3	IEDCUM

*Scheduled events are numbered 1-200. Repair event families are given numbers 201-560 since each of the 30 equipment repairs may call for a family of up to 12 repair events. Emergency events are given numbers 561-570 by the program corresponding to emergency types 1-10.

FORTRAN	Description
AASP	Average aspiration
ACP	Average crew pace
ADUR	Average duration of scheduled event
ADURIO	Internal variable
APST	Average psychological stress threshold
ART	Average repair time
ASD	Average standard deviation of repair
ASDE	Average standard deviation of emergency
BE	Effectivity of stress
CALRY	Number of calories required by average crewman per day
CN	Catnap length
DI	Alphanumeric descriptor array
DTBE	Duration time between emergencies
DTE	Duration time of emergencies
DTR	Duration time of repairs
DUMY	Internal variable
EDCV	Data change value
EMREVT	Emergency event data set
EQREVT	Repair event data set
FP1	Internal variable
FP2	Internal variable
FP3	Internal variable
FP4	Internal variable
FP5	Internal variable
GBG	Internal variable
I	Internal variable
ICLASS	Class
IDES	Description array
IDF	Day number of next failure for each piece of equipment
IDS	Number of duty shifts
IEC	Expected energy consumption
IECE	Expected energy consumption for emergency
IEDC	Data change variable
IEFN	Family number
IEFNX	Temporary variable
IERR	Error branch
IESS	Essentiality
IESSE	Emergency essentiality
IET	Essentiality threshold
IETYP	Event number
IFOI	Event number in family
IGRG	Internal array
IH	Event hazard class
IHE	Event hazard class (emergency)
II	Index variable
IND	Printout option indicator array
INT	Event code
IP1	Internal variable
IP2	Internal variable

FORTRAN	Description
IP3	Internal variable
IP4	Internal variable
IP5	Internal variable
IPE	Prerequisite event
IPERCT	Internal variable
IQR	Equipment list
IRC	Consumable rate of expenditure (units/hours)
IRC1	Consumable rate of expenditure (units)
IRCE	Consumable rate of expenditure (units/hours)--emergencies
IRCE1	Consumable rate of expenditure (units)--emergencies
IRE	Number of repair events
IREX	Repair event number maximum
ITEM	Temporary variable
ITER	Iteration number
J	Index variable
JJ	Index variable
K	Type of emergency
K1	Physical capacitation fraction
K7	Derating constant
KASE	Case number
KE	Event end type
KK	Index variable
KON	Initial level of consumables (units/hours)
KON1	Initial level of consumables (units)
KONT	Threshold consumables (units/hours)
KONT1	Threshold consumables (units)
LODM	Mental load
LODME	Mental load for emergency
MAXSL	Maximum sleep
MEN	Crew composition array
MM	Internal variable
MPI	Average number of man days per indidence of physical incapacitation
N	Number of iterations
ND	Number of days
NDBE	Number of days between emergencies
NDMAX	Maximum number of days
NDS	Duty shift
NEME	Number of emergencies
NEQRE	Number of equipments required
NFP1	Internal variable
NFP2	Internal variable
NFP3	Internal variable
NFP4	Internal variable
NFP5	Internal variable
NIF	Number of family
NIP1	Internal variable
NIP2	Internal variable
NIP3	Internal variable
NIP4	Internal variable

FORTRAN	Description
NIP5	Internal variable
NIQR	Equipment used array
NOSE	Number of scheduled events
NREQ	Number of men required by type for emergency
NTYPES	Number of types
NX	Next event number for each alternative
PARAM	Common block
PERSNL	Common block
PID	Average duration of physical incapacity
PPFQ	Per cent fully qualified in primary specialty
PPMQ	Per cent moderately qualified in primary specialty
PPUQ	Per cent unqualified in primary specialty
PRB	Probability for each alternative path
PTT	Cross training probability table
PTTT	Common block
PWRRT	Average short term power output
RELH	Equipment reliability
RELI	Intermittent reliability
RTU	Repair touchup code
SCHEVT	Internal variable
SESTA	Sea state
SIGWT	Standard deviation of body weight
SLEEP	Number of hours since last eight hour sleep period
SPFQ	Per cent fully qualified in secondary specialty
SPMQ	Per cent minimally qualified in secondary specialty
SPUQ	Per cent unqualified in secondary specialty
ST	Earliest starting time allowed
TFAT	Fatigue threshold
TL	Time limit by which event must be completed
TS	Consumable threshold set identifier (units/hours)
TS1	Consumable threshold set identifier (units)
TSE	Threshold set for consumables below which event is ignored (units/hours)
TSE1	Threshold set for consumables below which event is ignored (units)
TSR	Threshold set for consumables below which emergency is ignored (units)
TSR1	Threshold set for consumables below which emergency is ignored (units/hours)
TUI	Intermittent reliability
TYPE	Internal variable
USHLIM	Per cent threshold for unmanned station hours
WORK1	Number of hours worked after which no new work assignment is made
WORK2	Number of hours worked after which no new work is authorized
WT	Mean body weight
ZPC	Physical capability constant

FORTRAN	Description
EF	Goodness of physical capability value
EH	Event hazard
EMTBF	Equipment meantime between failures
EMTTR	Equipment meantime to repair
EPEFF	Equipment performance effectiveness
EPL	Equipment performance level
ES	Goodness of stress value
ESSS	Temporary variable
ETEM	Temporary variable
EXER	Overexertion factor used in physical capability calculation
FAT	Fatigue level for each man in crew
FDIFF	Failure difference
FLIC	Number of men in crew
FLIG	Number of crew members in group participation in current event
FLOAT	Conversion to real
FUNC	Function
GASP	Group aspiration level
GPACE	Group pace value used in performance time calculation
GPCC	Group physical capability
GPERF	Group performance
GSTR	Group stress
GSTRM	Group stress threshold
HEADR	Program header
HR	Hazard ratio used in SI calculations
HRSE	Total man hours worked on emergency events for the day
HRSR	Total man hours worked on repair events for the day
HRSS	Total man hours worked on scheduled events for the day
HSLS	Number of hours since last slept for each man in crew
I	Index variable
IAA	Number of men in crew for each echelon
IC	Maximum number of crewmen
ICE	Command echelon for each crewman
ICLASS	Class
ICML	Event with maximum CML for the day
ICSS	Current sea state
IDC	Calories expended for the day for each crewman
IDCMX	Event with maximum calories expended for the day
IDE	Day number of next occurrence for each emergency event
IDF	Day number of next failure for each piece of equipment
IDFFF	Internal variable
IDIFR	Internal variable
IDIFR	Internal variable
IDIFF	Internal variable
IDS	Number of duty shifts
IE	Event number
IEC	Expected energy consumption during event (calories per hour)
IECE	Expected energy consumption during emergency event (calories per hour)
IEDC	Data change variable
IEFN	Family number

FORTRAN	Description
AASP	Average aspiration
ABS	Absolute value
ACAL	Calories expended since last slept for each man in crew
ACART	Average repair time per day
ACP	Average crew pace
ACDT	Average dow time per day
ACUT	Average up time per day
ADUR	Average duration of scheduled event (hours)
ADUR2	One half of average duration
ADURIO	Average duration of scheduled event in type data
AEPL	Average equipment performance level
AMAX1	Maximum value
AMIN1	Minimum value
APA	Average performance adequacy
APST	Average psychological stress threshold
APW	Average physical workload for the day for each man in crew
ART	Average repair time
ASD	Standard deviation of ADUR
ASDE	Average standard deviation (emergency)
ASP	Level of aspiration at beginning of iteration for each man in crew
ATEM	Temporary variable
BE	Effectivity stress on performance on a no-stress state
BLANK	Temporary variable
BTEM	Temporary variable
CAL	Average calories expended per day for each man in crew
CALR	Intermediate calculation used in crew selection process
CALRY	Number of calories required by average crewman per day
CART	Current average repair time
CASP	Current level of aspiration for each man in crew
CCAL	Calories expended for the event for each man in crew
CCI	Initial crew competence
CDT	Current downtime
CLSDTA	Internal array for summary by event class
CLSDTR	Internal array for summary by event class
CML	Crew mental load
CMLMX	Maximum crew mental load obtained for an event during the day
CN	Catnap length. Below considered rest. Above is sleep.
CTEM	Temporary variable
CUT	Current uptime
DEPEFF	Average equipment performance effectiveness
DI	Alphanumeric descriptor array
DS	Amount of sleep for the day for each man in crew
DTBE	Duration time between emergencies
DTE	Duration time of emergencies
DTEM	Temporary variable
DTR	Duration time of repair
EA	Goodness of aspiration value
EC	Goodness of competence value
EDCV	Data change value

FORTRAN	Description
IEIE	Counter for number of different events attempted for the day
IEMAX	Maximum number of events
IESS	Event essentiality
IESSE	Emergency event essentiality
IET	Essentiality threshold. Determines ignores.
IETYP	Event type number
IEVENT	Event to be simulated for the day
IFIRST	Temporary variable
IFOI	Group member
IGAP	Internal variable
IGIND	Indicator for cause of ignored event
IGNOR	Indicator for ignored event (1= event ignored)
IH	Event hazard class (1-3= low, 4-6= medium, 7-9= heavy)
IHE	Event hazard class (emergency)
II	Index variable
III	Index variable
IKONC	Internal variable
IKONE	Internal variable
IND	Indicators for output recording options
INIF	Internal variable
INIQ	Internal variable
INT	Event code (1= normal, 2= training)
INVS	Inverse pointer array
IOIF	Operator induced failure
IPE	Prerequisite event
IPET	Previous event indicator
IPI	Incomplete processing indicator
IPS	Primary specialty for each crewman
IPSS	First 20 slots same as IPS, second 20 slots same as ISS
IPTR	Pointer array for events
IQMAX	Maximum number of pieces of equipment for repair events
IQR	Equipment list
IRC	Consumable rate of expenditure (units/hours)
IRC1	Consumable rate of expenditure (units)
IRCE	Consumable rate of expenditure for emergencies (units/hours)
IRCE1	Consumable rate of expenditure for emergencies (units)
IRE	Number of repair events
ISIE	Internal variable
ISS	Secondary specialty for each man in crew
IST	Internal variable
ISW1	Internal variable
ITAP	Tape option
ITEM	Temporary variable
ITER	Current interaction
ITRY	Counter for number of attempts with current event
ITYPE	Type for which man was selected for event for each man in group
IXDF	Internal variable
IXDF1	Internal variable
J	Internal variable

FORTRAN	Description
JI	Internal variable
JJ	Internal variable
JNDS	Internal variable
K	Type of emergency
K1	Fraction to which a man's physical capability is reduced
K7	Derating constant for acceptable performance
KA	Number of crew members available for selection for current event
KASE	Case number
KE	Event end time type (1= fixed end, 2= variable end)
KIND	Indicator in group selection process (0= searching primary specialties, 1= secondary)
KK	Internal variable
KMAX	Maximum number of types of emergency events
KON	Initial level of consumable (units/hours)
KON1	Initial level of consumable (units)
KONC	Current consumable level for each consumable (units/hours)
KONC1	Current consumable level for each consumable (units)
KONE	Consumables expended for the event for each man in group
KONE1	Consumables expended (units)
KONT	Consumable threshold (units/hours)
KONT1	Consumable threshold (units)
KOUNT	Internal variable
LI	Crewman chosen as leader for this event
LL	Internal variable
LMAX	Maximum number of consumables (units/hours)
LMAX1	Maximum number of spare parts consumables (units)
LODM	Event mental load (1-3 light, 406 medium, 7-9 heavy)
LODME	Mental load (emergencies)
LSHIFT	Internal variable
M	Crewman number
MA	Man selected for the event by type
MAT	Man selected for the event
MAVAIL	Man selected for the event
MAXSL	Maximum sleep permitted per day (hour)
MAXST	Maximum stress obtained for any event during the day
MAXSTE	Event on which maximum stress was obtained
MCHSN	Indicator for man selected for the event (0= not selected; 1= selected)
MEN	Crew composition, number of men of each type by crew selection
MPCC	Maximum physical capability for the day for each man in crew
MPI	Average number of man days per indices of physical incapacitation
N	Number of mission iterations per computer run
ND	Number of days, current number
NDAYS	Total number of days in the simulation (updated after each iteration completed)
NDBE	Number of days between emergencies
NDMAX	Maximum number of days

FORTRAN	Description
NDS	Duty shifts
NE	Number of emergency events to be simulated this day
NEME	Temporary variable
NEQRE	Number of equipments (emergencies)
NFALE	Number of failures for this day
NIF	Number in family
NIGNR	Number of ignored events for this day
NIQR	Number of equipments in repair
NKASES	Number of cases
NKOUNT	Internal variable
NN	Temporary variable
NOFAIL	Number of failures for iteration for each crewman
NOIF	Number of operator induced failures (counter)
NOIFT	Total number of operator induced failures
NOSE	Number of scheduled events
NOSE1	Temporary variable
NOSUC	Number of successes for iteration for each man in crew
NPI	Number of crewmen to be incapacitated this day
NPRFM	Number of events performed
NPTR	Pointer array if in event sequencing
NR	Repair number, number of repair events to be simulated this day
NREPT	Number of events repeated this day
NREQ	Number of men of each type required by event
NREQE	Number of men of each type required for an emergency
NREQT	Number of men required for the event for each type
NS	Sickness indicator for each man in crew (0= well, 1= sick)
NSUC1	Number of successes on the first try this day
NSUC2	Number of successes on the second try this day
NTMAX	Maximum number of types of personnel
NU	Number of successes for the day for each crewman
NUMFAM	Number of families
NX	Next event number for each alternative
PA	Performance adequacy
PACE	Working pace for each man in crew
PAF	Pace adjustment factor used in calculations GPACE
PC	Physical capability at iteration start for each crewman
PCC	Current physical capability for each crewman
PCDUM	Equipment to PPFQ, PPMQ, PPU, SPFQ, SPMQ, SPUQ
PCOM	Primary competence for each crewman
PEA	Temporary variable
PEFF	Performance effectiveness
PERF	Performance level for each crewman
PI	Physical incapacity for each crewman
PI2	Number of future days of physical incapacity for each crewman
PID	Average duration of physical incapacity (days)
PPFQ	Per cent of crew fully qualified in primary specialty
PPMQ	Per cent of crew minimally qualified in primary specialty
PPUQ	Per cent of crew unqualified in primary specialty
PRB	Probability of each alternative path after current event
PSCOM	PCOM (1-20) and SCOM (1-20)

FORTRAN	Description
PSESIC	Per cent seasick
PT	Performance time for each event
PTR	Sequencial order of events for the day
PTT	Cross training probability table. Given primary by secondary.
PWR	Average short term power output rate for each crewman
PWRRT	Average short term power output rate for average crewman (calories/hours)
RELH	Equipment reliability
RELI	Intermittent reliability
REPAIR	Variable to determine if event is repair event
REPTM	Repair time
RSSUC2	Number of repair successes on second try
RTEMP	Temporary variable
RTU	Action if event performance is unsatisfactory (1= repeat, 2= touchup, 3= no action)
SCOM	Secondary competence for each man in crew
SCDTIQ	Summation of down time
SEF	Efficiency factor
SESTA	Sea state
SF	Slowness factor used in computing GPACE
SFDIFF	Failure difference
SFTHRS	Shift hours
SGEM	System general effectiveness measure
SI	Safety index
SIDC	Total calories expended this event
SIDCMX	Maximum SIDC for any event this day
SIGWT	Standard deviation for work time
SLEEP	Number of hours since last 8 hour sleep period
SPFQ	Per cent of crew fully qualified by crewman at mission start
SPL	System performance level
SPMQ	Per cent of crew minimally qualified in secondary specialty
SPUQ	Per cent of crew unqualified in secondary specialty
SRL	System reliability level
ST	Earliest starting time allowed (hours)
STAR	Star
STRM	Psychological stress for each crewman
SUCC	Evaluation indicators for each man eligible for the event
TAVAIL	Testing criterion for each man eligible for the event
SUCC	Evaluation indicators for each man eligible for the event
TEH	Total event hazard for the day
TEM1	Temporary variable
TEM2	Temporary variable
TEM3	Temporary variable
TEMP	Temporary variable
TFAT	Fatigue threshold below which sleep is not authorized
THW	Total hours worked for the crew for the day
TITLE	Program title
TL	Time limit by which event must be completed (hours)
TPCOM	Temporary primary competence

FORTRAN	Description
TPSCOM	Temporary/secondary competence array
TS	Consumable threshold set identifier (units/hour)
TS1	Consumable threshold set identifier (units)
TSCOM	Temporary secondary competence
TSE	Consumable threshold for emergencies (units/hours)
TSE1	Consumable threshold emergencies (units)
TUI	Intermittent failure rate
TW	Working time for the day for each crewman
TWP	Working time in primary specialty for each crewman
TWS	Working time in secondary specialty for each crewman
USH	Unmanned station hours for the current event
USHLIM	Per cent threshold for unmanned station hours
USHT	Total unmanned station hours for the day
V	Value of time function used in computing performance time
WH	Time since last event participation for each crewman, wait hours
WORK1	Number of hours worked after which no new assignments are made
WORK 2	Number of hours worked after which further work is not authorized
WT	Mean body weight of total population (lbs)
YU	Internal variable
Z	Last real time worked this day for each crewman
Z1	Earliest time when all group members are available
Z2	Earliest time current event can begin
ZC	Real time of completion for each event
ZPC	Physical capability constant
ZTEMP	Temporary variable

IPUYSN Function Subprogram

FORTRAN	Description
IPUYSN	Uniform probability test function
K	Temporary probability variable
PAR	Type of emergency
TEST	Temporary variable
Y	Temporary variable

FBUILD Function Subprogram

FORTRAN	Description
FBUILD	Function subprogram
H	Temporary variable
HSLS	Hours since last slept
TEM1	Temporary variable

FORTRAN	Description
AASP	Average aspiration
ACART	Average repair time per day
ACDT	Average down time per day
ACP	Average crew pace
ACUT	Average up time per day
ADALY	Internal array for daily summary
AEPL	Average equipment performance level
APA	Average performance adequacy
APST	Average psychological stress threshold
APW	Average physical workload
ASP	Aspiration
ASPA	Temporary aspiration
AVACA	Total ACART per day
AVACD	Total ACDT per day
AVACU	Total ACUT per day
AVAEP	Total AEPL per day
AVDEP	Total DEPEFF per day
BE	Effectivity of stress on performance
CAL	Average calories expended per day for each man in crew
CALRY	Number of calories required by average crewman per day
CART	Current average repair time
CARTI	Internal array for average repair time
CASP	Current aspiration
CCAL	Current calorie level
CDT	Current down time
CDTI	Internal array for downtime
CI	Blanks
CLSDTA	Internal array for summary by event class
CLSDTI	Internal array for summary by event class
CLSDTR	Internal array for summary by event class
CML	Crew mental load
CMLMX	Crew mental load (maximum)
CN	Catnap length
CUT	Current up time
CUTI	Internal array for uptime
DALY	Output array
DEPEFF	Average equipment performance effectiveness
DI	Alphanumeric description array
DS	Amount of sleep for the day
EDCV	Data change value

FORTRAN	Description
EMTBF	Equipment mean time between failures
EMTTR	Equipment mean time to repair
EPEFF	Equipment performance effectiveness
EPL	Equipment performance level
EQYPTA	Equipment availability
EQYPTA	Equipment reliability
FAT	Fatigue
FD	Temporary variable
FEMTBF	Equipment MTTR
FLIC	Crew size (floating point)
FLITER	Iteration (floating point)
FLOAT	Floating point
FNTE	Number of total events (floating point)
HMNAV	Human availability
HMNRL	Human reliability
HMTTR	Human MTTR
HRSE	Hours worked on emergency
HRSR	Hours worked on repairs
HRSS	Hours worked on scheduled events
HSLS	Hours since last slept
HSLSA	Reinitialization of hours since last slept
I	Internal variable
IAA	Crew echelon number
IC	Maximum number of crewmen
ICF	Command eschelon
ICML	Crew mental load
ICSS	Current sea state
IDALY1	Internal array for daily summary
IDC	Data change
IDCMX	Data change maximum
IDFR	Repair identification
IEDC	Data change variable
IEFN	Family number
IET	Essentiality threshold
IETYP	Event type number
IFOI	Event number in family code
IITEH	Temporary variable
IJ	Internal variable
IKØNC	Internal variable
IMTAB	Output array
IND	Indicators
IPE	Prerequisite event
IPS	Primary specialty
IQMAX	Maximum number of pieces of equipment or repair events
ISS	Secondary specialty for each man in crew
ITER	Iteration
J	Temporary variable
JITER	Internal array for daily summary
K	Type of emergency
K1	Fraction to which a man's physical capability is reduced after daily quota is done

FORTRAN	Description
K7	Derating constant for acceptable performance
KK	Internal variable
KON	Initial level of consumable (units/hours)
KON1	Initial level of consumables (units)
KONC	Current consumable level (units/hours)
KONC1	Current consumable level (units)
KONT	Consumable threshold (units/hours)
KONT1	Consumable threshold (units)
MAXSL	Maximum sleep permitted per day
MAXST	Maximum stress for any event
MAXSTE	Event of maximum stress
MPCC	Maximum physical capability
N	Number of iterations
N1S1	Internal variable
ND	Number of days
NDAYS	Days in simulation
NDMAX	Maximum number of days
NE	Number of emergency events
NEME	Temporary variable
NEQRE	Number of equipments emerging
NFALE	Number of failures this day
NIF	Number in family
NIGNR	Number of events ignored
NOSE	Number of scheduled events
NPRFM	Number of events performed
NR	Number of repairs
NREI	Total repairs for the run
NREPT	Number of repeats
NSUC1	Number of successes in first try
NSUC2	Number of successes in second try
NTF	Total number of events
NTIPL	Number of men in each type
NU	Number of daily successes by crewman
NX	Next event number for each alternative
OUTA	Internal array
OUTB	Output array
PACE	Working pace
PACEA	Reinitialization of work pace
PC	Physical capability
PCA	Reinitialization of physical capability
PCC	Current physical capability
PCOM	Primary competence
PCOMA	Reinitialization of primary competence
PEFF	Performance effectiveness
PERF	Performance level by crewman
PI	Physical incapability
PI2	Number of future days of physical incapacity for each crewman
PIA	Reinitialization of physical capacity by crewman
PRR	Probability for each alternative path after current event

FORTRAN	Description
PWR	Average short term output for average crewman
PWRRT	Average short term output for average crewman
RELI	Intermittent reliability
REMT	Temporary variable for equipment mean time between failure
REMTR	Temporary variable for equipment mean time to repair
REPTM	Repair time
REPTMD	Repair time per day
RSSUCZ	Number repair successes on second try
RSSUC2D	Internal variable
RSTØT	Total number of successes on second try for all iterations
RTU	Action if event performance is unsatisfactory
SCDTIQ	Summation of CDT
SCOM	Secondary competence
SCOMA	Secondary competence reinitialized
SESTA	Sea state
SFDIPF	Failure difference
SGEM	General system measure
SI	Safety index
SIDMX	Maximum calories expended for this event
SLEEP	Number of hours since last 8 hour sleep period
SPL	System performance level
SRL	System reliability leve;
ST	Earliest starting time allowed (hours)
STRM	Stress threshold
SYSA	System availability
SYSRL	System reliability
T3	Temporary variable
TDALY	Daily total output array
TEH	Total daily event hazard
TEM1	Temporary variable
TEM3	Temporary variable
TFAT	Fatigue threshold
TIITER	Iteration summary array
TL	Time limit by which event must be completed (hours)
TOT	Internal variable
TOUTA	Internal array
TPCOM	Temporary primary competence
TS	Consumable threshold set identification (units/hours)
TS1	Consumable threshold set identifier (units)
TSCOM	Temporary secondary competence
TW	Time worked
TWP	Time worked in primary
TWS	Time worked in secondary
USHT	Unmanned station hours
USHLIM	Per cent threshold for unmanned station hours
WORK1	Number of hours worked after which no new assessment is made
WORK2	Number of hours worked after which further work is not authorized
ZTEM	Temporary variable

APPENDIX B PROGRAM LISTINGS

This appendix contains the program listings for the digital simulation models as follows:

- Appendix B1 - Program listing for the 1-2 man digital simulation model
- Appendix B2 - Program listing for the 4-20 man digital simulation model

APPENDIX B1 - PROGRAM LISTING

This appendix contains the program listing for the 1-2 man digital simulation program.

```
PROGRAM      PAR4
                                              CDC 6600 FTN V3.0-P243 OPT=1  3/24/71  11.51.36.
      CPAR4  PROGRAM PAR4(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
                   PAIR 4 - MAIN - NEW FORMATS- JUNE 1970
C           THIS DECK (PAR3) HAS CHANGES 1, 2, 3, 4, AND 9
C           CHANGE NO. 9 IS THE CYCLIC WAIT
            COMMON /PLT/ PV1(25,2,7),  PV2(25,2,3),  HEAD(8),  STABLE(400),
           1 STAX(100)
            COMMON /B1/ TYPE(300,2), ESS(300,2), IPREC(300,2), TMBEG(300,2),
           1 NXTS(300,2), NXTF(300,2), AVGTM(300,2), AVGTMD(300,2),
           2 PRBSUC(300,2), TMLE(300,2), TMLN(300,2), NTASK(2), ISJT(300,2),
           3 NXTJ(300,2), NXTJP(300,2)
            COMMON /B2/  STRM(2),SPEED(2),TRAVA(2),NUMTRL,NRUN,NUMIT,
           1 CWAIT(2),SWAIT(2),PRD(2),TMUP(2)
            COMMON/B3/ TMU(2)     ,ITASK(2)   ,IRAND(2)   ,XRAND(2)   ,
           2 TOTTMI(2),   TIME(2),
           3 IFPEOL(300,2),ADDSTR(2),  STR(2),        STRS(2),     ISTRS(2),
           4 JFLAG(7),    IFREQ(300,2),  AUGSTR(2),   COMES(300,2),JPW(2),
           4 LST(2)    ,J
           5 IND2       ,IND3      ,JP         ,I          ,IP        ,IND1
           6 ITER       ,IN       ,ID    ,IND4    ,IGNORE     ,PI        ,TWOPI     ,
                                         ,TOTTMS(2)     ,IND5      ,IND6
            COMMON /B4/ ATU(2),  ATW(2),  APS(2),  AFS(2),  IFREQF(300,2)
            COMMON /NEW/ ISUMF(2), ISUMI(2), ICHNG, IPKF(300,2),
           1 SUMTF(300,2), ATMU(300,2), IAVG(300,2), ASTS(300,2),IASTS(300,2),
           2 TSUMTF(2), NUMCOH(300,2), SUMCOH(300,2), COHLAS(2),
           3 AVGCOH(300,2), DFMAX(2), VGOAL(2)
            COMMON/NEWR/NIJIJP, NSETF(50), NSETS(50), NSETFP(50),
           1 NSETSP(50), ISETI(50), ISETJ(50), ISETIP(50), ISETJP(50)
            COMMON /ABCD/ TITLE(12)
            DIMENSION ALPH(3),IPRECS(2)
C           DIMENSION CONVER(3)
            DIMENSION HOL(16)
            DIMENSION BLOCK(4),KBLK(4)
            DATA HOL /6HD      ,6HJ      ,6HN      ,6HE      ,6HF      ,6H
           1 6HI      ,6H*     ,6HWAIT   ,6HG      ,6H JOINT,6H  TASK,
           2 6HS      ,6H UNDER,6H  OVER,6HC      /
C              HOL(1)  = D
C              HOL(2)  = J
C              HOL(9)  = WAIT
C              HOL(8)  = *
C              HOL(7)  = I
C              HOL(6)  = H
C              HOL(5)  = F
C              HOL(4)  = E
```

```
C          HOL(3)  = N
C          HOL(10) = G
C          HOL(11) =  JOINT
C          HOL(12) =    TASK
C          HOL(13) = S
C          HOL(14) =  UNDER
C          HOL(15) =    OVER
C          HOL(16) = C
 7011 FORMAT (12A6)

      READ(5,7011) (TITLE(I),I=1,12)

      IN=5
      IO = 6
      PI=3.1415926536
      TWOPI=6.2831853072
      CONVER(1)=3600.
      CONVER(2)=1.
      CONVER(3)=60.
      ICHECK=0

      NIJIJP = 0
      NRUN=1
      ICALL = 1

      NUMSUC = 0
      PRSUC = 0.0

      TOTTMI(1) = 0.0
      TOTTMI(2) = 0.0

      IFLG1 = 0
      ISUMF(1) = 0
      ISUMF(2) = 0
      ISUMI(1) = 0
      ISUMI(2) = 0
      TSUMIF(1) = 0.0
      TSUMIF(2) = 0.0

      DO 10 I=1,300
      DO 10 J=1,2
      ESS(I,J) = HOL(6)
      ATMU(I,J) = 0.0
      ASTS(I,J) = 0.0
      SUMTF(I,J) = 0.0
      IASTS(I,J) = 0
      IAVG(I,J) = 0
      IPKF(I,J) = 0
      NUMCOH(I,J) = 0
      SUMCOH(I,J) = 0.0
   10 CONTINUE

  600 CALL INPUT(ICALL)

C           PRE-RUN THE RANDOM NUMBER GENERATORS INDI TIMES
```

```
      XRAND = RANF(IND1)
      NBASE = 3192471
      CALL SETBASE(NBASE)
      D = 1.
    5 CONTINUE
      INDX=IND2
      CON=CONVER(INDS+1)
  650 CALL RESET(1,THINT)
      GO TO 850
  700 ICALL=2
      CALL INPUT(ICALL)
      INDX=IND2
      CON=CONVER(INDS+1)
      IF (ICALL.EQ.1) NRUN=1
      NUMSUC=0
  750 CALL RESET(1,THINT)
      GO TO 850
C        800 IS THE START OF THE NEXT ITERATION FROM STATEMENT 6053
  800 CALL RESET(2,THINT)
      IPRECS(1)=0
      IPRECS(2)=0
C
C  ARE TASK DETAILS REQUIRED
  850 IF (INDX.LE.1) GO TO 1030
C
      WRITE (10,905) ITER,NRUN,NUMTRL
  905 FORMAT (1H1/28H  DETAIL OUTPUT OF ITERATION,I4,3X,3HRUN,I4,5X,
     1 5H TASK,I4//
     2 22X,10HOPERATOR 1,58X,10HOPERATOR 2//
     362H TASK TASK NON  STRESS   -----   T I M E S   -----  SFI  COMES.
     4 7X,
     562H TASK TASK NON  STRESS   -----   T I M E S   -----  SFI  COMES,
     6 49H  NO  TYPE ESS IND  TOT     WAIT    TASK      CUM,20X,
     7 49H  NO  TYPE ESS IND  TOT     WAIT    TASK      CUM)
 1030 IF (TMU(J).LE.TMU(JP)) GO TO 1050
 1040 JT=J
      J=JP
      JP=JT
 1050 I=ITASK(J)
      IGNONE=0
      ISUC=0
      IP=ITASK(JP)
 1060 IF(ITYPE(I,J) .NE. HOL(I)) GO TO 1060
C  DECISION SUBTASK
```

```
      ISUC = 0
      XRAND = RANF(IND1)
      IF (XRAND.LE.PRBSUC(I,J)) ISUC=1
      TIME(J) = 0.0
      GO TO 4061
C        DOES SPECIAL JUMP TASK CODE = 2
 1080 IF(ISJT(I,J) .NE. 2)  GO TO 1084
      XRAND = RANF(IND1)
      TIME(J) = 0.0
      IF(XRAND .GT. PRBSUC(I,J))  GO TO 1082
C        SUCCESSFUL
      ISUC = 1
      GO TO 4061
C        FAILURE
 1082 ISUC = 0
C        KEEP COUNT OF TOTAL SPECIAL JUMP TASKS, CODES 1 AND/OR 2
C        WITHIN EACH ITERATION
      NIJIJP = NIJIJP + 1
      ISETI (NIJIJP) = I
      ISETJ (NIJIJP) = J
      ISETIP(NIJIJP) = IP
      ISETJP(NIJIJP) = JP
      NSETF (NIJIJP) = NXTF(I,J)
      NSETS (NIJIJP) = NXTS(I,J)
      NSETFP(NIJIJP) = NXTF(IP,JP)
      NSETSP(NIJIJP) = NXTS(IP,JP)
      NXTF(I,J) = NXTJ (I,J)
C     NXTS(I,J) = NXTJ(I,J)
      IP = NXTJP(I,J)
      ITASK(JP) = IP
      GO TO 4061
 1084 ICHECK = ICHECK+1
      II=IPREF(I,J)
      IF(II.LE.0) GO TO 2000
      IF (ITASK(JP)    .GT.II) GO TO 2000
      IF(ICHECK .LT. 3)  GO TO 1040
      WRITE(6,1087)
 1087 FORMAT (////30X,59H*************************************************,
     1**********//47X,25HMUTUAL PARTNER WAIT BLOCK)
      STOP
 2000 ICHECK=0
      IF (TMU(J).GE.TMREG(I,J)) GO TO 2010
```

```
      TOTTMI(J)=TOTTMI(J)+TMREG(I,J)-TMU(J)
      TMU(J)=TMREG(I,J)
      GO TO 1030
 2010 IF(TYPE(I,J) .NE. HOL(2))  GO TO 2300
      IF(TYPE(IP,JP) .NE. HOL(2))  GO TO 1040
      JWAIT=J
      JNWAIT=JP
      IF (TMU(J).LT.TMU(JP)) GO TO 2020
      JWAIT=JP
      JNWAIT=J
 2020 TOTTMI(JWAIT)=TOTTMI(JWAIT)+TMU(JNWAIT)-TMU(JWAIT)
      TMU(JWAIT)=TMU(JNWAIT)
C
C  EQUIPMENT REPAIR TASK
 2300 CONTINUE
      IF(TYPE(I,J) .NE. HOL(4))  GO TO 2500
      STR(J)=1.
      RDEV = DEV(D)
      TIME(J)=AVGTM(I,J)+RDEV*AVGTMD(I,J)
      GO TO 3000
 2500 IF (TMU(J).LE.TMAVA(J)) GO TO 2505
      STR(J)=STRM(J)
      IF (STR(J).LE.STRS(J)) GO TO 2620
      STRS(J)=STR(J)
      ISTRS(J)=1
      GO TO 2620
 2505 JJ=J
      II=I
      IGO=1
 2510 T1=TMAVA(JJ)-TMU(JJ)
      T2=TMLE(II,JJ)
      T3=TMLN(II,JJ)
      IF  (SPFED(JJ)*(T2+T3).GT.T1) GO TO 2600
      STR(JJ)=1.
      GO TO (2700,2710),IGO
 2600 IF (SPEED(JJ)*T2.GT.T1) GO TO 2610
      STR(JJ)=1.
      GO TO (2620,2710),IGO
 2610 STR(JJ)=T2/T1
      IF (STR(JJ).LT.1.) STR(JJ)=1.
      IF (STR(JJ).GT.5.) STR(JJ)=5.
      IF (JJ.EQ.JP) GO TO 2615
      IF (STRS(JJ).GE.STR(JJ)) GO TO 2615
      STRS(JJ)=STR(JJ)
      ISTRS(JJ)=1
 2615 CONTINUE
      GO TO (2620,2710),IGO
 2620 IF(ESS(I,J) .NE. HOL(3))  GO TO 2700
      IGNONE=1
      ISUC=1
      TIME(J)=.6/CON
      TIME(J)=0.
      IFREQ(I,J)=IFREQ(I,J)+1
```

```
      IF(ISJT(I,J) .NE. 1)  GO TO 3050
C        KEEP COUNT OF TOTAL SPECIAL JUMP TASKS. CODES 1 AND/OR 2
C          WITHIN EACH ITERATION
      NIJIJP = NIJIJP + 1
      ISETI (NIJIJP) = I
      ISETJ (NIJIJP) = J
      ISETIP(NIJIJP) = IP
      ISETJP(NIJIJP) = JP

      NSETF (NIJIJP) = NXTF(I,J)
      NSETS (NIJIJP) = NXTS(I,J)
      NSETFP(NIJIJP) = NXTF(IP,JP)
      NSETSP(NIJIJP) = NXTS(IP,JP)
C                NOW SET TO JUMP TASK NUMBER
      NXTF(I,J) = NXTJ (I,J)
      NXTS(I,J) = NXTJ (I,J)
      NXTF(IP,JP) = NXTJP(I,J)
      NXTS(IP,JP) = NXTJP(I,J)

C  ADDED STRESS = PREVIOUS ADDED STRESS (CALCULATION GOES HERE)
      GO TO 3050
 2700 AUGSTR(J)=STR(J)

      RDEV = DEV(D)

      TEM=AVGTM(I,J)+RDEV*AVGTMD(I,J)

C                CALCULATE COHESIVE
      COHES(I,J) = ((STR(J)*STR(JP))-1.0)/((STRM(J)*STRM(JP))-1.0)
C                SAVE LAST COHES CALCULATED FOR EACH SUB TASK

      COHLAS(J) = COHES(I,J)
C                GET SUMMATION OF COHESIVE AND ALSO COUNT

      SUMCOH(I,J) = SUMCOH(I,J) + COHES(I,J)
      NUMCOH(I,J) = NUMCOH(I,J) + 1


      IF(TYPE(I,J) .EQ. HOL(2))  GO TO 2705
      IF ((IPREC(I,J).EQ.IPRECS(J)) GO TO 2715
 2705 JJ=JP
      II=IP
      IGO =2
      GO TO 2510
 2710 ADDSTR(J)=1.
```

```
      IF (STR(JP).LE.STRM(JP)) ADDSTR(J)=(STR(JP)-1.)/(STRM(JP)-1.)
      IF (STR(JP).EQ.1.) ADDSTR(J)=0.
      AUGSTR(J)=STR(J)+ADDSTR(J)
C     COMES(I,J)=
 2715 CONTINUE
          ADD CYCLIC CALCULATIONS -- TYPE  C
C         USES NEW INPUT PARAMETER  PRD -- PERIOD IN SECONDS
C
      IF(TYPE(I,J) .NE. HOL(16))  GO TO 2716
      BLOCK(J) = AMOD(THU(J),PRD(J))
      ITHUP = THU(J)/PRD(J)
      THUP(J) = ITHUP
      IF(BLOCK(J) .NE. 0.0)  THUP(J) = THUP(J)+1.0
      THUP(J) = THUP(J)*PRD(J)
          CALCULATE TOTAL TIME WAIT
C     TOTTMI(J) = THUP(J)-THU(J)
          THEN SET OLD TIME USED = TO NEW TIME USED
C     THU(J) = THUP(J)
          KEEP AN ITERATION SUMMARY OF CYCLIC WAIT
C     CWAIT(J) = CWAIT(J)+TOTTMI(J)
          KEEP A RUN SUMMARY OF CYCLIC WAIT
C     SWAIT(J) = SWAIT(J)+TOTTMI(J)
 2716 IF(AUGSTR(J).GE.STRM(J)) GO TO 2720
      SOM=(STR(J)-1.)/(STRM(J)-1.)
      ZTEMP=-1.829*SOM**3+3.7622*SOM**2-2.35075*SOM+1.
      TIME(J)=TEM*SPEED(J)*ZTEMP
      TIME(J)=TEM*SPEED(J)/STR(J)
C     GO TO 3000
 2720 IF (AUGSTR(J).GT.STRM(J)+1.) GO TO 2730
      TIME(J) =((2.*AUGSTR(J)-2.*STRM(J)+1.)*TEM-(AUGSTR(J)-STRM(J))*
     2    AVGTM(I,J))*SPEED(J)
      GO TO 3000
 2730 TIME(J)=(3.*TEM-AVGTM(I,J))*SPEED(J)

 3000 XRAND = RANF(IND1)
      ISUC=0
      IF(STR(J).GE.STRM(J)) GO TO 3020
      IF (((STRM(J)-1.)*XRAND-STR(J)+1.)/ (STRM(J)-STR(J)).LE.
     2    PRBSUC(I,J)) ISUC=1
      GO TO 3050
 3020 IF (STR(J).GT.STRM(J)+1.) GO TO 3040
      IF ((STR(J) -STRM(J)+XRAND)/(STR(J)-STRM(J)+1.).LE.PRBSUC(I,J))
     2   ISUC=1
      GO TO 3050
 3040 IF(.5*(XRAND+1.).LE.PRBSUC(I,J)) ISUC=1
 3050 CONTINUE
```

```
      TMIN=.75/CON
      TIME(J)=AMAX1(TIME(J),TMIN )
 4000 TMU(J)=TMU(J)+TIME(J)
      IF(TYPE(I,J) .NE. HOL(2))  GO TO 4020
      TMU(JP)=TMU(J)
 4020 IF (I.GT.IPREC(IP,JP)) GO TO 4060
      IF (TMU(J).GT.TMU(JP)) GO TO 4040
 4030 JPW(JP)=1
      GO TO 4061
 4040 TIMEW=TMU(J)-TMU(JP)
      TMU(JP)=TMU(J)
      TOTTMI(JP)=TOTTMI(JP)+TIMEW
      GO TO 4030
 4060 JPW(JP)=0
 4061 IF (TMU(J).LT.TMAVA(J)) GO TO 4080
      IF (JFLAG(J).EQ.1) GO TO 4080
      JFLAG(J)=1
      IFREQL(I=1,J)=IFREQL(I=1,J)+1
 4080 IF(TYPE(I,J) .NE. HOL(2))  GO TO 5000
      IF (TMU(JP).LT.TMAVA(JP)) GO TO 5000
      IF (JFLAG(JP).EQ.1) GO TO 5000
      JFLAG(JP)=1
      IFREQL(IP-1,JP)=IFREQL(IP-1,JP)+1
C
 5000 CONTINUE
C
      SFI = HOL(5)
      IF(ISUC .EQ. 1)  SFI = HOL(6)
      IF(IGNORE .EQ. 1)  SFI = HOL(7)
      IF(SFI .NE. HOL(5))  GO TO 9010
C         DO NOT ADD FAILURES OF FOLLOWING 2 TYPES
C           (1)  A DECISION TASK -- TYPE D
C           (2)  SPECIAL JUMP TASK -- CODE 2
      IF(TYPE(I,J) .EQ. HOL(1) .OR. ISJT(I,J) .EQ. 2)  GO TO 9010

      IFREOF(I,J) = IFREOF(I,J) + 1
      IF(TYPE(I,J) .EQ. HOL(2)) IFREOF(IP,JP) = IFREOF(IP,JP) + 1
 9010 OT = HOL(6)
      IF(TMU(J) .GT. TMAVA(J))  OT = HOL(8)
      ALPH(1) = HOL(6)
      ALPH(2) = HOL(6)
      ALPH(3) = HOL(6)
      IF(JPW(JP) .EQ. 1)  ALPH(3) = HOL(9)

C         CALCULATE AVERAGE START TOTAL STRESS PER TASK PER OPERATOR
      ASTS(I,J) = ASTS(I,J)+AUGSTR(J)
C         KEEP COUNT OF NUMBER OF TASKS
      IASTS(I,J) = IASTS(I,J)+1

C         CALCULATE SUMMATION OF FAILURE TIMES
C         HOL(5) IS F
      IF(SFI .NE. HOL(5))  GO TO 5003
C         FAILURE
      SUMTF(I,J) = SUMTF(I,J)+TIME(J)
```

```
      IF(TYPE(I,J) .EQ. HOL(2))  SUMTF(IP,JP) = SUMTF(IP,JP)+TIME(JP)
C        THEN GO TO 5001
      GO TO 5001
C        CALCULATE AVERAGE CUMULATIVE TASK TIMES COMPLETED
C        OF SUCCESSFUL TASKS.
 5003 ATMU(I,J) = ATMU(I,J)+TMU(J)
C        KEEP COUNT OF SUCC. TASKS.
      IAVG(I,J) = IAVG(I,J)+1
C
C
C  ARE TASK DETAILS REQUIRED
 5001 IF(INDX .LE. 1)  GO TO 5050
C
C
      IF(TYPE(I,J) .NE. HOL(2))  GO TO 5002
      ALPH(1) = HOL(11)
      ALPH(2) = HOL(12)
 5002 IF (J.EQ.2) GO TO 5008
      WRITE(6,5005) I,TYPE(I,J),ESS(I,J),STR(J),AUGSTR(J),TOTTMI(J),
     1 TIME(J),TMU(J),OT,SFI,COMES(I,J),ALPH
 5005 FORMAT (I4,4X,A1,3X,A1,F6.2,F5.2,2F8.2,F10.2,A1,2X,A1,F8.2,
     1 9X,2A6,14X,A6)
      GO TO 5050
 5008 WRITE(6,5009) ALPH,I,TYPE(I,J),ESS(I,J),STR(J),AUGSTR(J),
     1 TOTTMI(J),TIME(J),TMU(J),OT,SFI,COMES(I,J)
 5009 FORMAT (2X,2A6,14X,A6,35X,I4,4X,A1,3X,A1,F6.2,F5.2,2F8.2,
     1 F10.2,A1,2X,A1,F8.2)
 5050 CONTINUE
      IF(SFI .EQ. HOL(6))  SFI = HOL(13)
      ISAVE=I
      IPRECS(J)=IPREC(I,J)
      TOTTMS(J)=TOTTMS(J)+TOTTMI(J)
      TOTTMI(J)=0.
      IF (ISUP.NE.1) GO TO 5200
      LST(J)=I
      IF (IGNORE.EQ.1) GO TO 5060
      IF(TYPE(I,J) .NE. HOL(2))  GO TO 5060
      LST(JP)=IP
 5060 IF(TYPE(I,J) .NE. HOL(2))  GO TO 5080
      IF (IP.NE.NTASK(JP)) GO TO 5070
      IF (JFLAG(JP).EQ.1) GO TO 5080
      IFREQL(IP,JP)=IFREQL(IP,JP)+1
      GO TO 5080
 5070 IP=NXTS(IP,JP)
      ITASK(JP)=IP
 5080 IF (I.NE.NTASK(J)) GO TO 5100
      IF (JFLAG(J).EQ.1) GO TO 5090
```

```
      IFRFOL(I,J)=IFHEOL(I,J)+1
 5090 IF (LST(JP).EQ.NTASK(JP)) GO TO 6000
      GO TO 1000
 5100 I=NXTS(I,J)
      GO TO 5300
 5200 I=NXTP(I,J)
 5300 ITASK(J)=1
      IGNORE = 0
      IF (LST(JP).EQ.NTASK(JP)) GO TO 1060
      IF(IPREC(IP,JP) .EQ. ISAVE .AND. TYPE(IP,JP) .NE. HOL(2))JPW(JP)=0
      IF (JPW(JP).EQ.1)GO TO 1060
      GO TO 1030
C                               -----
C WRITE ITERATION SUMMARY -----
 6000 CONTINUE
      OV = HOL(14)
      IF(JFLAG(1) .EQ. 1 .OR. JFLAG(2) .EQ. 1)  OV = HOL(15)
      IF(OV .EQ. HOL(14)) NUMSUC = NUMSUC+1
      STABLE(ITER)=(FLOAT(NUMSUC)/FLOAT(ITER))*100.
      TOTALT=AMAX1(TMU(1),TMU(2))
C         COMPUTE PEAK STRESS FREQUENCY
      IZ = ISTRS(1)
      IPKF(IZ,1) = IPKF(IZ,1)+1
      IZ = ISTRS(2)
      IPKF(IZ,2) = IPKF(IZ,2)+1
C         IF OVER RUN, SET STRESS TO STRESS THRESSHOLD
C         HOL(14) = UNDER
      IF(OV .EQ. HOL(14)) GO TO 6009
      STR(1) = STRM(1)
      STR(2) = STRM(2)
C  IS ITERATION SUMMARY REQUIRED
 6009 IF(INDX .LE. 0)  GO TO 6051
      WRITE (IO,6010) ITER,NRUN,NUMTPL,OV,TOTALT
 6010 FORMAT (1H ///    29H SUMMARY OUTPUT OF ITERATION ,I4,6X, 4HRUN ,
     2 I4,6X,6HTRIAL ,I4/6X,A6,4H RUN,5X,17H  TOTAL TIME USED,F11.2//
     3 18H OPR  THRES  SPEED,40H   - - - - -   T I M E S   - - - - -
     4 11HPEAK STRESS,4X,5HFINAL,4X,6HLAST,4X,6HCYCLIC/
     5 18H NO   HOLD,13X,5HAVAIL,7X,4HUSED,4X,4HDIFF,3X,4HWAIT,3X,
     6 4HTASK,4X,5HVALUE,3X,6HSTRESS,3X,5HCOMES,4X,4HWAIT)
      DO 6050 K=1,2
      DT=TMU(K)-TMAVA(K)
      WRITE (IO,6040) K,STRM(K),SPEED(K),TMAVA(K),TMU(K),DT,TOTTMS(K),
     2 ISTMS(K),STRS(K),STR(K),COMLAS(K),CWAIT(K)
 6040 FORMAT (I3,F8.2,F7.2,2F11.2,2F7.1,I7,2F9.2,2F8.2)
 6050 CONTINUE
```

```
 6051 CONTINUE
C         TEST TO SEE IF EITHER/OR A CODE 1 OR 2 SPECIAL JUMP TASK
C         WAS EXECUTED
      IF(NIJIJP .EQ. 0)  GO TO 9000
      DO 8888 KIKI=1,NIJIJP
      KI = ISETI(KIKI)
      KJ = ISETJ(KIKI)
      KIP = ISETIP(KIKI)
      KJP = ISETJP(KIKI)
      NXTF (KI,KJ)    = NSETF (KIKI)
      NXTS (KI,KJ)    = NSETS (KIKI)
      NXTF (KIP,KJP)  = NSETFP(KIKI)
      NXTS (KIP,KJP)  = NSETSP(KIKI)
 8888 CONTINUE
C         RESET COUNTER FOR NEXT ITERATION OR RUN
      NIJIJP = 0
 9000 DO 6052 K=1,2
      ATU(K)=ATU(K)+TMU(K)
      APS(K)=APS(K)+STRS(K)
      AFS(K)=AFS(K)+STR(K)
 6052 ATW(K)=ATW(K)+TOTTMS(K)
      ITER=ITER+1
C         DOES OUTPUT FORMAT CHANGE
      IF(ITER .LE. ICHNG)  GO TO 6053
      IF(INDX .NE. IND2)  GO TO 6053
      INDX = INDX-IND3
C         DO WE GO BACK FOR ANOTHER ITERATION
 6053 IF(ITER .LE. NUMIT)  GO TO 800
C WRITE RUN DATA
      FLIT=ITER-1
      DO 6054 K=1,2
      ATU(K)=ATU(K)/FLIT
      APS(K)=APS(K)/FLIT
      AFS(K)=AFS(K)/FLIT
 6054 ATW(K)=ATW(K)/FLIT
      TEMP=AMAX1(THAVA(1),THAVA(2))
      PRSUC=(FLOAT(NUMSUC)/FLIT)*100.
      DO 6055 K=1,2
      PV1(NRUN,K,1)=ATU(K)
      PV1(NRUN,K,2)=APS(K)
      PV1(NRUN,K,3)=AFS(K)
      PV1(NRUN,K,4)=PRSUC
      PV1(NRUN,K,5) = ATW(K)
      PV2(NRUN,K,1)=THAVA(K)
      PV2(NRUN,K,2)=STRN(K)
 6055 PV2(NRUN,K,3)=SPEED(K)
```

```
      WRITE (IO,6070) NRUN,NUMIT,NUMSUC,PRSUC, TEMP
 6070 FORMAT (1H1/ 23H SUMMARY OUTPUT OF RUN ,I4/ 23H  NUMBER OF ITERATI
     2ONS ,I4/ 23H   NUMBER OF SUCCESSES ,I4/ 23H    PER CENT SUCCESSES
     3 ,F6.1, 7X, 19H FOR TIME DURATION ,F9.2)
      WRITE (IO,6080)
 6080 FORMAT (/ 83H OPR  THRES  SPEED  - - - - - - AVERAGE TIMES - - - -
     1 - -    PEAK     FINAL     CYCLIC/
     2 18H NO   HOLD,13X,5HAVAIL,7X,4HUSED,5X,4HDIFF,6X,4HWAIT,
     3 3X,6HSTRESS,3X,6HSTRESS,4X,4HWAIT)
      DO 6090 K=1,2
      TEMP1=ATU(K)-TMAVA(K)
 6090 WRITE (IO,6094) K,STRH(K),SPEED(K),TMAVA(K),ATU(K),TEMP1,ATW(K),
     2 APS(K),AFS(K),SWAIT(K)

 6094 FORMAT (I3,F8.2,F7.2,2F11.2,2F8.2,3F9.2)

      WRITE (IO,6097)
 6097 FORMAT (1H // 15H FREQUENCY DATA/ 73H TASK  LAST TASK COMPLETED
     2- - -TASK FAILED- - -    ---TASK IGNORED----/ 73H  NO        OP 1
     3 OP 2           OP 1          OP 2        OP 1  NF   OP 2  NE)

      NMAX=MAX0(NTASK(1),NTASK(2))

      T1=0.0
      T2=0.0

      DO 6020 K=1,NMAX

C        DO SUMMATION OF TASKS FAILED AND IGNORED.
      ISUMF(1) = ISUMF(1)+IFREOF(K,1)
      ISUMF(2) = ISUMF(2)+IFREOF(K,2)
      ISUMI(1) = ISUMI(1)+IFREQ(K,1)
      ISUMI(2) = ISUMI(2)+IFREQ(K,2)

 6020 WRITE (IO,6030) K, IFREOL(K,1),IFREOL(K,2),IFREOF(K,1)    ,IFREOF
     2 (K,2)    , IFREQ (K,1),ESS(K,1),IFREQ(K,2),ESS(K,2)
 6030 FORMAT( I4,I10,I7,I13,6X  ,I6,6X  ,I5,3X,A1,I7,3X,A1)

C          ADD TO PLOT
C            SUM OF TASKS IGNORED
C            SUM OF TASKS FAILED
      PVI(NRUN,1,6) = ISUMI(1)
      PVI(NRUN,2,6) = ISUMI(2)
      PVI(NRUN,1,7) = ISUMF(1)
      PVI(NRUN,2,7) = ISUMF(2)

C        FLOAT THE SUMMATION OF TASKS FAILED AND IGNORED

      BLOCK(1) = ISUMF(1)
      BLOCK(2) = ISUMF(2)
      BLOCK(3) = ISUMI(1)
      BLOCK(4) = ISUMI(2)

C          CALCULATE AVERAGES OF
```

```
C            TASKS FAILED
C            TASKS IGNORED
      BLOCK(1) = BLOCK(1)/FLIT
      BLOCK(2) = BLOCK(2)/FLIT
      BLOCK(3) = BLOCK(3)/FLIT
      BLOCK(4) = BLOCK(4)/FLIT
      WRITE(6,7000) ISUMF(1),ISUMF(2),ISUMI(1),ISUMI(2),
     1 BLOCK(1),BLOCK(2),BLOCK(3),BLOCK(4)
 7000 FORMAT (30X,5H-----,7X,5H-----,6X,5H-----,6X,5H-----/
     1 18X,5HTOTAL,7X,I4,8X,I4,7X,I4,7X,I4//
     2 18X,7HAVERAGE,4X,F5.1,7X,F5.1,6X,F5.1,6X,F5.1)
C        NEW PAGE FOR MORE OUTPUT AFTER SUMMARY OUTPUT OF RUN
      WRITE(6,7002) NRUN
 7002 FORMAT (1H1,5X,21HSUMMARY OUTPUT OF RUN,I4///)
      WRITE(6,7004)
 7004 FORMAT (5H TASK,4X,13HFAILURE TIMES,4X,11HPEAK STRESS,6X,
     1 15HAVG TIME CMPLTD,4X,20HAVG START TOT STRESS,4X,12HAVG COHESIVE/
     2 4H  NO.5X,
     3 4HOP 1,5X,4HOP 2,4X,4HOP 1,3X,4HOP 2,6X,4HOP 1,5X,4HOP 2,7X,
     4 4HOP 1,8X,4HOP 2,5X,4HOP 1,4X,4HOP 2)
      DO 3330 K=1,NMAX
      IF(IAVG(K,1) .NE. 0)  GO TO 3303
      A1 = 0.0
      GO TO 3304
 3303 A1 = ATWU(K,1)/FLOAT(IAVG(K,1))
 3304 IF(IAVG(K,2) .NE. 0)  GO TO 3305
      A2 = 0.0
      GO TO 3306
 3305 A2 = ATWU(K,2)/FLOAT(IAVG(K,2))
 3306 IF(IASTS(K,1) .NE. 0)  GO TO 3307
      A3 = 0.0
      GO TO 3308
 3307 A3 = ASTS(K,1)/FLOAT(IASTS(K,1))
 3308 IF(IASTS(K,2) .NE. 0)  GO TO 3309
      A4 = 0.0
      GO TO 3310
 3309 A4 = ASTS(K,2)/FLOAT(IASTS(K,2))
C            CALCULATE AVERAGE COHESIVE
 3310 IF(NUMCOH(K,1) .NE. 0)  GO TO 3311
      AVGCOH(K,1) = 0.0
      GO TO 3312
 3311 AVGCOH(K,1) = SUMCOH(K,1)/FLOAT(NUMCOH(K,1))
 3312 IF(NUMCOH(K,2) .NE. 0)  GO TO 3313
      GO TO 3320
 3313 AVGCOH(K,2) = SUMCOH(K,2)/FLOAT(NUMCOH(K,2))
 3320 WRITE(6,7006) K,SUMTF(K,1),SUMTF(K,2),IPKF(K,1),IPKF(K,2),
     1 A1,A2,A3,A4,AVGCOH(K,1),AVGCOH(K,2)
```

```
 7006 FORMAT (I4,2F9.2,4X,I3,4X,I3,2X,2F9.2,F11.2,F12.2,F9.2,F8.2)

 3330 CONTINUE
C        CALCULATE TOTAL OF FAILURE TIMES

      DO 22 K=1,NMAX
      TSUMTF(1) = TSUMTF(1) + SUMTF(K,1)
      TSUMTF(2) = TSUMTF(2) + SUMTF(K,2)
   22 CONTINUE

      WRITE(6,7008) TSUMTF(1),TSUMTF(2)
 7008 FORMAT (7X,16H-------  -------/4X,2F9.2,7H  TOTAL//)
C        CALCULATE AVERAGE OF FAILURE TIMES

      TSUMTF(1) = TSUMTF(1)/FLIT
      TSUMTF(2) = TSUMTF(2)/FLIT

      WRITE(6,7009) TSUMTF(1),TSUMTF(2)
 7009 FORMAT (4X,2F9.2,9H  AVERAGE)

      DO 25 K=1,300
      DO 25 L=1,2
      ATMU(K,L) = 0.0
      SUMTF(K,L) = 0.0
      ASTS(K,L) = 0.0
      IAVG(K,L) = 0
      IPKF(K,L) = 0
      IASTS(K,L) = 0
      COMFS(K,L) = 0.0
      SUMCOM(K,L) = 0.0
      NUMCOM(K,L) = 0
   25 CONTINUE

      ISUMF(1) = 0
      ISUMF(2) = 0
      ISUMI(1) = 0
      ISUMI(2) = 0
      TSUMTF(1) = 0.0
      TSUMTF(2) = 0.0

      NRUN=NRUN+1
      GO TO 700
      END
```

PROGRAM PAR4 CDC 6600 FTN V3.0-P243 OPT=1 -3/24/71 11.51.36.

CARD NO.	SEVERITY		DIAGNOSTIC
111	I	XRAND	ARRAY NAME OPERAND NOT SUBSCRIPTED, FIRST ELEMENT WILL BE USED
167	I	XRAND	ARRAY NAME OPERAND NOT SUBSCRIPTED, FIRST ELEMENT WILL BE USED
168	I	XRAND	ARRAY NAME OPERAND NOT SUBSCRIPTED, FIRST ELEMENT WILL BE USED
175	I	XRAND	ARRAY NAME OPERAND NOT SUBSCRIPTED, FIRST ELEMENT WILL BE USED
177	I	XRAND	ARRAY NAME OPERAND NOT SUBSCRIPTED, FIRST ELEMENT WILL BE USED
373	I	XRAND	ARRAY NAME OPERAND NOT SUBSCRIPTED, FIRST ELEMENT WILL BE USED
377	I	XRAND	ARRAY NAME OPERAND NOT SUBSCRIPTED, FIRST ELEMENT WILL BE USED
381	I	XRAND	ARRAY NAME OPERAND NOT SUBSCRIPTED, FIRST ELEMENT WILL BE USED
384	I	XRAND	ARRAY NAME OPERAND NOT SUBSCRIPTED, FIRST ELEMENT WILL BE USED

```
      PROGRAM      PAR4                                      CDC 6600 FTN V3.0-P243 OPT=1   -3/24/71  11.51.36.

      SYMBOLIC REFERENCE MAP

 ENTRY POINTS
  4052  PAR4

 VARIABLES      SN  TYPE               RELOCATION
  1152  ADDSTR      REAL        ARRAY    B3              6  AFS       REAL        ARRAY    B4
  6761  ALPH        REAL        ARRAY                    4  APS       REAL        ARRAY    B4
  4545  ASTS        REAL        ARRAY    NEW          2265  ATMU      REAL        ARRAY    NEW
     0  ATU         REAL        ARRAY    B4              2  ATW       REAL        ARRAY    B4
  1154  AUGSTR      REAL        ARRAY    B3          11311  AVGCOM    REAL        ARRAY    NEW
  7020  AVGTM       REAL        ARRAY    B1          10150  AVGTMD    REAL        ARRAY    B1
  6754  A1          REAL                              6755  A2        REAL
  6756  A3          REAL                              6757  A4        REAL
  7011  BLOCK       REAL        ARRAY                 1156  COMES     REAL        ARRAY    B3
 11307  COMLAS      REAL        ARRAY    NEW          6710  CON       REAL
  6766  CONVER      REAL        ARRAY                   11  CWAIT     REAL        ARRAY    B3
  6706  D           REAL                             12441  DFMAX     REAL        ARRAY    NEW
  6742  DT          REAL                              1130  ESS       REAL        ARRAY    B1
  6750  FLIT        REAL                               764  HEAD      REAL        ARRAY    P/T
  6771  HOL         REAL        ARRAY                 3446  I         INTEGER              B3
  5675  IASTS       INTEGER     ARRAY    NEW          3415  IAVG      INTEGER     ARRAY    NEW
  6701  ICALL       INTEGER                           6700  ICHECK    INTEGER
     4  ICHNG       INTEGER              NEW          6704  IFLG1     INTEGER
  2312  IFREQ       INTEGER     ARRAY    B3             10  IFREQF    INTEGER     ARRAY    B4
    22  IFREQL      INTEGER     ARRAY    B3           3454  IGNORE    INTEGER              B3
  6721  IGO         INTEGER                           6714  II        INTEGER
  3460  IN          INTEGER              B3           6707  INDX      INTEGER
  3450  IND1        INTEGER              B3           3451  IND2      INTEGER              B3
  3452  IND3        INTEGER              B3           3453  IND4      INTEGER              B3
  3464  IND5        INTEGER              B3           3465  IND6      INTEGER              B3
  3461  IO          INTEGER              B3           3447  IP        INTEGER              B3
     5  IPKF        INTEGER     ARRAY    NEW          2260  IPREC     INTEGER     ARRAY    B1
  6764  IPRECS      INTEGER     ARRAY                    4  IRAND     INTEGER     ARRAY    B3
  6735  ISAVE       INTEGER                            311  ISETI     INTEGER     ARRAY    NEWR
   455  ISETIP      INTEGER     ARRAY    NEWR          373  ISETJ     INTEGER     ARRAY    NEWR
   537  ISETJP      INTEGER     ARRAY    NEWR        14712  ISJT      INTEGER     ARRAY    B1
    20  ISTRS       INTEGER     ARRAY    B3           6713  ISUC      INTEGER
     0  ISUMF       INTEGER     ARRAY    NEW             2  ISUMI     INTEGER     ARRAY    NEW
     2  ITASK       INTEGER     ARRAY    B3           3457  ITER      INTEGER              B3
  6726  ITMUP       INTEGER                           6740  IZ        INTEGER
  3444  J           INTEGER              B3           2310  JFLAG     INTEGER     ARRAY    B3
  6720  JJ          INTEGER                           6716  JNWAIT    INTEGER
  3445  JP          INTEGER              B3           2306  JPW       INTEGER     ARRAY    B3
  6712  JT          INTEGER                           6715  JWAIT     INTEGER
  6741  K           INTEGER                           7015  KBLK      INTEGER    *UNDEF
  6744  KI          INTEGER                           6743  KIKI      INTEGER
  6746  KIP         INTEGER                           6745  KJ        INTEGER
  6747  KJP         INTEGER                           6760  L         INTEGER
  3442  LST         INTEGER     ARRAY    B3           6705  NHASE     INTEGER
     0  NIJIJP      INTEGER              NEWR         6753  NMAX      INTEGER
     7  NRUN        INTEGER              B2              1  NSETF     INTEGER     ARRAY    NEWR
   145  NSETFP      INTEGER     ARRAY    NEWR           63  NSETS     INTEGER     ARRAY    NEWR
   227  NSETSP      INTEGER     ARRAY    NEWR        14710  NTASK     INTEGER     ARRAY    B1
```

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        PROGRAM     PAR4                                          CDC 6600 FTN V3.0-P243 OPT=1  -3/24/71  11.51.36.

VARIABLES      SN  TYPE          RELOCATION
  7027  NUMCOM     INTEGER   ARRAY   NEW            10  NUMIT      INTEGER             B1
  6702  NUMSUC     INTEGER                           6  NUMTRL     INTEGER             B1
  5670  NXTF       INTEGER   ARRAY   B1          16042  NXTJ       INTEGER   ARRAY     B1
 17172  NXTJP      INTEGER   ARRAY   B1           4540  NXTS       INTEGER   ARRAY     B1
  6734  OT         REAL                           6736  OV         REAL
  3455  PI         REAL              B3          11300  PRBSUC     REAL      ARRAY     B1
    15  PRO        REAL      ARRAY   B2           6703  PRSUC      REAL
     0  PV1        REAL      ARRAY   PLT           536  PV2        REAL      ARRAY     PLT
  6717  RDEV       REAL                           6733  SFI        REAL
  6727  SOM        REAL                              2  SPEED      REAL      ARRAY     B1
   774  STABLE     REAL      ARRAY   PLT          1614  STAX       REAL      ARRAY     PLT
    14  STP        REAL      ARRAY   B3              0  STRM       REAL      ARRAY     B1
    16  STPS       REAL      ARRAY   B3          10157  SUMCOM     REAL      ARRAY     NEW
  1135  SUMTF      REAL      ARRAY   NEW            13  SWAIT      REAL      ARRAY     B1
  6725  TEM        REAL                           6751  TEMP       REAL
  6752  TEMP1      REAL                             12  TIME       REAL      ARRAY     B3
  6732  TIMEW      REAL                              0  TITLE      REAL      ARRAY     ABCD
     4  TMAVA      REAL      ARRAY   B2           3410  TMBEG      REAL      ARRAY     B1
  6731  TMIN       REAL                           6711  TMINT      REAL
 12430  TMLE       REAL      ARRAY   B1          13560  TMLN       REAL      ARRAY     B1
     0  TMU        REAL      ARRAY   B3             17  TMUP       REAL      ARRAY     B1
  6737  TOTALT     REAL                             10  TOTTMI     REAL      ARRAY     B3
  3462  TOTTMS     REAL      ARRAY   B3           7025  TSUMTF     REAL      ARRAY     NEW
  3456  TWOPI      REAL              B3              0  TYPE       REAL      ARRAY     B1
  6722  T1         REAL                           6723  T2         REAL
  6724  T3         REAL                          12443  VGOAL      REAL      ARRAY     NEW
     6  XRAND      REAL      ARRAY   B3           6730  ZTEMP      REAL

FILE NAMES          MODE
     0  INPUT                 2022  OUTPUT                       0  TAPE5       FMT          2022  TAPE6

EXTERNALS           TYPE    ARGS
        DEV        REAL       1                          INPUT                1
        RANF       REAL       1                          RESET                2
        SETRASE               1

INLINE FUNCTIONS    TYPE    ARGS
        AMAX1      REAL       0  INTRIN                  AMOD       REAL      2  INTRIN
        FLOAT      REAL       1  INTRIN                  MAX0       INTEGER   0  INTRIN

STATEMENT LABELS
     0  5           INACTIVE               0  10                          0  21
     0  25                                 0  600     INACTIVE            0  650       INACTIVE
  4136  700                                0  750     INACTIVE         4154  800
  4160  850                             6323  905    FMT               4174  1030
  4200  1040                            4203  1050                     4210  1060
  4230  1080                            4246  1082                     4276  1084
  6366  1087      FMT                   4317  2000                     4334  2010
  4356  2020                            4363  2300                     4402  2500
  4414  2505                            4420  2510                     4442  2600
  4456  2610                            4502  2615                     4510  2620
  4555  2700                            4607  2705                     4614  2710
  4635  2715                            4664  2716                     4702  2720
  4720  2730                            4726  3000                     4750  3020
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        PROGRAM     PAR4                                          CDC 6600 FTN V3.0-P243 OPT=1   3/24/71  11.51.36.

STATEMENT LABELS
  4766  3040                              4776  3050                              6122  3303
  6125  3304                              6132  3305                              6135  3306
  6142  3307                              6145  3308                              6152  3309
  6155  3310                              6162  3311                              6165  3312
  6171  3313                              6174  3320                                 0  3330
     0  4000        INACTIVE              5013  4020                              5023  4030
  5025  4040                              5033  4060                              5035  4061
  5050  4080                              5071  5000                              5210  5001
  5223  5002                              5202  5003                              6402  5005    FMT
  5270  5008                              6412  5009    FMT                       5331  5050
  5364  5060                              5405  5070                              5412  5080
  5425  5090                              5431  5100                              5435  5200
  5441  5300                              5464  6000                              5521  6009
  6422  6010    FMT                          0  6020                              6563  6030    FMT
  6462  6040    FMT                          0  6050                              5603  6051
     0  6052                              5652  6053                                 0  6054
     0  6055                              6470  6070    FMT                       5511  6080    FMT
     0  6090                              6533  6094    FMT                       6540  6097    FMT
  6570  7000    FMT                       6604  7002    FMT                       6611  7004    FMT
  6636  7006    FMT                       6644  7008    FMT                       6652  7009    FMT
  6321  7011    FMT                          0  8888                              5627  9000
  5131  9010

COMMON BLOCKS   LENGTH
        PLT       1008
        B1        8402
        B2          17
        B3        1846
        B4         608
        NFW       5413
        NEWR       401
        ABCD        12

STATISTICS
  PROGRAM LENGTH   27578     1519
   BUFFER LENGTH   40448     2084
   COMMON LENGTH  424538    17707
```

CDC 6600 FTN V3.0-P243 OPT=1 3/24/71 11.51.36.

```
RESET          SUBROUTINE RESET - 635 VERSION
      SUBROUTINE RESET(ICALL,TMINT)
C  TMINT CAN BE USED TO RETURN TIME OF A RANDOM INTERUPT (CALCULATED FOR
C  EACH ITERATION)

      COMMON /B1/ TYPE(300,2), ESS(300,2), IPREC(300,2), TMBEG(300,2),
     1 NATS(300,2), NXTF(300,2), AVGTM(300,2), AVGTMD(300,2),
     2 PRBSUC(300,2), TMLE(300,2), TMLN(300,2), NTASK(2), ISJT(300,2),
     3 NXTJT(300,2), NXTJP(300,2)

      COMMON /B2/  STRM(2),SPEED(2),TMAVA(2),NUMTRL,NRUN,NUMIT,
     1 CWAIT(2),SWAIT(2),PRD(2),TMUP(2)

      COMMON/B3/ TMU(2)     ,ITASK(2)  ,IRAND(2)  ,XRAND(2)  ,
     2 TOTTMI(2),   TIME(2),      STR(2),      STRS(2),      ISTRS(2),
     3 IFREQL(300,2),ADDSTR(2),  AUGSTR(2),   COMES(300,2),JPW(2),
     4 JFLAG(2),      IFREQ(300,2),
     4 LST(2)    ,J          ,JP          ,I          ,IP        ,IND1
     5 IND2      ,IND3       ,IND4        ,IGNORE     ,PI        ,TWOPI
     6 ITER     ,IN      ,IO      ,TOTTMS(2)     ,IND5     ,IND6

      COMMON /B4/ ATU(2),  ATW(2),  APS(2),  AFS(2),  IFREQF(300,2)

      COMMON /NEW/ ISUMF(2), ISUMI(2), ICHNG, IPKF(300,2),
     1 SUMTF(300,2), ATMU(300,2), IAVG(300,2), ASTS(300,2),IASTS(300,2),
     2 TSUMTF(2), NUMCOH(300,2), SUMCOH(300,2), COMLAS(2),
     3 AVGCOM(300,2), DFMAX(2), VGOAL(2)

      ISUC=0
      J=1
      JP=2
      IGNORE=0
      DO 20 K=1,2
      CWAIT(K) = 0.0
      ITASK(K)=1
      TMU(K)=0.
      JPW(K)=0
      JFLAG(K)=0
      TOTTMS(K)=0.
      LST(K)=0
      TIME(K)=0.
      STR(K)=1.
      STRS(K)=1.
      ISTRS(K)=1
      ADDSTR(K)=0.
      AUGSTR(K)=0.
   20 CONTINUE
      IF (ICALL-1) 30,40,30
   30 RETURN
   40 ITEM=MAX0(NTASK(1),NTASK(2))
      DO 50 K=1,2
      SWAIT(K) = 0.0
      ATU(K)=0.
      ATW(K)=0.
      APS(K)=0.
```

```
SUBROUTINE  RESET                                  CDC 6600 FTN V3.0-P243 OPT=1   3/24/71  11.51.36.

                 AFS(K)=0.
                 DO 50 L=1,ITEM
                 IFREQ(L,K)=0
                 IFREQL(L,K)=0
                 IFREQF(L,K)=0
              50 CONTINUE
                 ITEM=1
                 RETURN
                 END
```

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```
SUBROUTINE  RESET                                  CDC 6600 FTN V3.0-P243 OPT=1   3/24/71  11.51.36.

SYMBOLIC REFERENCE MAP

ENTRY POINTS
    2  RESET

VARIABLES      SN  TYPE              RELOCATION
  1152  ADDSTR     REAL       ARRAY    B3              6  AFS        REAL       ARRAY     B4
     4  APS        REAL       ARRAY    B4           4545  ASTS       REAL       ARRAY     NEW
  2265  ATMU       REAL       ARRAY    NEW             0  ATU        REAL       ARRAY     B4
     2  ATW        REAL       ARRAY    B4           1154  AUGSTR     REAL       ARRAY     B3
 11311  AVGCOM     REAL       ARRAY    NEW          7020  AVGTM      REAL       ARRAY     B1
 10150  AVGTMD     REAL       ARRAY    B1           1156  COMES      REAL       ARRAY     B3
 11307  COMLAS     REAL       ARRAY    NEW            11  CWAIT      REAL       ARRAY     B2
 12441  DFMAX      REAL       ARRAY    NEW          1130  ESS        REAL       ARRAY     B1
  3446  I          INTEGER             B3           5675  IASTS      INTEGER    ARRAY     NEW
  3415  IAVG       INTEGER    ARRAY    NEW             0  ICALL      INTEGER              F.P.
     4  ICHNG      INTEGER             NEW          2312  IFREQ      INTEGER    ARRAY     B3
    10  IFREQF     INTEGER    ARRAY    B4             22  IFREQL     INTEGER    ARRAY     B3
  3454  IGNORE     INTEGER             B3           3460  IN         INTEGER              B3
  3450  IND1       INTEGER             B3           3451  IND2       INTEGER              B3
  3452  IND3       INTEGER             B3           3453  IND4       INTEGER              B3
  3464  IND5       INTEGER             B3           3465  IND6       INTEGER              B3
  3461  IO         INTEGER             B3           3447  IP         INTEGER              B3
     5  IPKF       INTEGER    ARRAY    NEW          2260  IPREC      INTEGER    ARRAY     B1
     4  IRAND      INTEGER    ARRAY    B3          14712  ISJT       INTEGER    ARRAY     B1
    20  ISTRS      INTEGER    ARRAY    B3             53  ISUC       INTEGER
     0  ISUMF      INTEGER    ARRAY    NEW             2  ISUMT      INTEGER    ARRAY     NEW
     2  ITASK      INTEGER    ARRAY    B3             55  ITEM       INTEGER
  3457  ITER       INTEGER             B3           3444  J          INTEGER              B3
  2310  JFLAG      INTEGER    ARRAY    B3           3445  JP         INTEGER              B3
  2306  JPW        INTEGER    ARRAY    B3             54  K          INTEGER
    56  L          INTEGER                          3442  LST        INTEGER    ARRAY     B3
     7  NRUN       INTEGER             B2          14710  NTASK      INTEGER    ARRAY     B1
  7027  NUMCOM     INTEGER    ARRAY    NEW            10  NUMIT      INTEGER              B2
     6  NUMTRL     INTEGER             B2           5670  NXTF       INTEGER    ARRAY     B1
 16042  NXTJ       INTEGER    ARRAY    B1          17172  NXTJP      INTEGER    ARRAY     B1
  4540  NXTS       INTEGER    ARRAY    B1           3455  PI         REAL                 B3
 11300  PRBSUC     REAL       ARRAY    B1             15  PRO        REAL       ARRAY     B2
     2  SPEED      REAL       ARRAY    B2             14  STR        REAL       ARRAY     B3
     0  STRM       REAL       ARRAY    B2             16  STRS       REAL       ARRAY     B3
 10157  SUMCOM     REAL       ARRAY    NEW          1135  SUMTF      REAL       ARRAY     NEW
    13  SWAIT      REAL       ARRAY    B2             12  TIME       REAL       ARRAY     B3
     4  TMAVA      REAL       ARRAY    B2           3410  TMBEG      REAL       ARRAY     B1
     0  TMINT      REAL       *UNUSED    F.P.      12430  TMLE       REAL       ARRAY     B1
 13560  TMLN       REAL       ARRAY    B1              0  TMU        REAL       ARRAY     B3
    17  TMUP       REAL       ARRAY    B2             10  TOTTMI     REAL       ARRAY     B3
  3462  TOTTMS     REAL       ARRAY    B3           7025  ISUMTF     REAL       ARRAY     NEW
  3456  TWOPI      REAL                B3              0  TYPE       REAL       ARRAY     B1
 12443  VGOAL      REAL       ARRAY    NEW             6  XRAND      REAL       ARRAY     B3

INLINE FUNCTIONS    TYPE    ARGS
       MAX0         INTEGER    0  INTRIN
```

```
      SUBROUTINE  RESET                              CDC 6600 FTN V3.0-P243 OPT=1  ^3/24/71  11.51.36.

STATEMENT LABELS
    0  20                                    0  30       INACTIVE             27  40
    0  50

COMMON BLOCKS    LENGTH
      B1          8402
      B2            17
      B3          1846
      B4           608
      NEW         5413

STATISTICS
  PROGRAM LENGTH     57B      47
   COMMON LENGTH  37436B   16206
```

```
CINPUT        SUBROUTINE INPUT - RAM VERSION        CDC 6600 FTN V3.0-P243 OPT=1  3/24/71  11.51.36.
      SUBROUTINE INPUT (ICALL)
      COMMON /PLT/ PV1(25,2,7),  PV2(25,2,3),  HEAD(8),  STABLE(400),
     1 STAX(100)
      COMMON /B1/ TYPE(300,2), ESS(300,2), IPREC(300,2), TNBEG(300,2),
     1 NXTS(300,2), NXTF(300,2), AVGTN(300,2), AVGTND(300,2),
     2 PRBSUC(300,2), TNLE(300,2), TNLN(300,2), NTASK(2), ISJT(300,2),
     3 NXTJ(300,2), NXTJP(300,2)
      COMMON /B2/  STRN(2),SPEED(2),TNAVA(2),NUMTRL,NRUN,NUMIT,
     1 CWAIT(2),SWAIT(2),PRD(2),TNUP(2)
      COMMON/B3/ TNU(2)      ,ITASK(2)  ,IRAND(2)  ,RRAND(2)  ,
     2 TOTTNI(2),   TIME(2),      STR(2),       STRS(2),      ISTRS(2),
     3 IFREQL(300,2),ADDSTR(2),  AUGSTR(2),    COMES(300,2),JPW(2),
     4 JFLAG(2),    IFREQ(300,2),
     4 LST(2)   ,J        ,JP        ,I         ,IP        ,IND1
     5 IND2     ,IND3     ,IND4      ,IGNORE    ,PI        ,TWOPI
     6 ITER     ,IN       ,ID        ,TOTTNS(2)    ,IND5   ,IND6
      COMMON /B4/ ATU(2),  ATW(2),  APS(2),  AFS(2),  IFREQF(300,2)
      COMMON /NEW/ ISUNF(2), ISUNI(2), ICHNG, IPKF(300,2),
     1 SUNTF(300,2), ATNU(300,2), IAVG(300,2), ASTS(300,2),IASTS(300,2),
     2 TSUNTF(2), NUNCOM(300,2), SUMCOM(300,2), COMLAS(2),
     3 AVGCOM(300,2), DFMAX(2), VGOAL(2)
      COMMON /ABCD/ TITLE(12)
      COMMON /RANS/ OLPROB(300,2), JAG(300,2),  JOT(2)
      DATA HOL/6HN      /
      DO 2 J = 1,2
      DO 2 I = 1,300
      PRBSUC(I,J) = OLPROB(I,J)
    2 CONTINUE
      IF (ICALL.NE.1) GO TO 252
      GO TO 76
   50 CONTINUE
      NRUN=NRUN-1
   74 READ(5,75) ID1,ID2,ID3,ID4,HEAD
   75 FORMAT (4I5,8A6)
      IF (ID1.LE.0) GO TO 76
      GO TO 74
   76 CONTINUE
      ICALL =1
      NTASK(1)=0
      NTASK(2)=0
      READ (IN,100) NUMTRL,NUMRUN,NUMIT,IND1,IND2,IND3,IND4,IND5,ICHNG
      IF (NUMIT.EQ.0) STOP 1111
  100 FORMAT (9I5)
```

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```
SUBROUTINE  INPUT                                    CDC 6600 FTN V3.0-P243 OPT=1  -3/24/71  11.51.36.
        101 FORMAT (8F10.0)
        105 READ(IN,1000) NINPC
       1000 FORMAT (I5)
            DO 122 KM = 1,NINPC
            READ (IN,110) J,I,TYPE(I,J),ESS(I,J),IPREC(I,J),THBEG(I,J),
          2  NXTS(I,J),NXTF(I,J),AVGTM(I,J),AVGTMD(I,J),PROBSUC(I,J),
          3 TMLE(I,J),TMLN(I,J),ISJT(I,J),NXTJ(I,J),NXTJP(I,J), JAG(I,J)
        110 FORMAT(I1,1X,I3,1X,A1,1X,A1,I3,F8.2,I4,I4,F9.2,F8.2,F5.2,F9.2,
          2F8.2,I2,I3,I3, I1 )
      C         SAVE THE HIGHEST TASK NUMBER FOR EACH OPERATOR
            IF(NTASK(J) .LT. I)  NTASK(J) = I
            OLPROB(I,J) = PROBSUC(I,J)
        122 CONTINUE
      C
      C  WERE TRE AND TRN READ IN
        130 IF (IND4.EQ.1) GO TO 151
      C  NO - COMPUTE THEM
            DO 150 K=1,2
            TUN=0.
            TES=0.
            L=NTASK(K)+1
        145 L=L-1
            IF (L.LE.0) GO TO 150
            IF(ESS(L,K) .EQ. HOL    )  TUN = TUN+AVGTM(L,K)
            IF(ESS(L,K) .NE. HOL    )  TES = TES+AVGTM(L,K)
            TMLE(L,K)=TES
            TMLN(L,K)=TUN
            GO TO 145
        150 CONTINUE
        151 CONTINUE
      C
            WRITE (IO,200) NUMTRL,NUMRUN,NUMIT
        200 FORMAT ( 1H1,/13X,13H TASK NUMBER ,I5/11X, 15HNUMBER OF RUNS ,I5,
          2   5X, 21HNUMBER OF ITERATIONS I5)
            J=1
        210 WRITE (IO,220) J
        220 FORMAT (1H ///24H TASK DATA FOR OPERATOR ,I6//96H TASK TASK NON
          1PRECEDENCE NEXT-TASK  AVERAGE     TIME PROB.     TIME REMAINING
          2PEC. JUMP TASK/95H  NO  TYPE ESS TASK   TIME SUC  FAIL   TIME
          3 DEV    SUC     ESS     NON-ESS  CODE  OP1  OP2, 6H    JAG/)
        225 K=NTASK(J)
            IF (K.LE.0) GO TO 245
            DO 230 I=1,K
        230 WRITE (IO,240) I,TYPE(I,J),ESS(I,J),IPREC(I,J),THBEG(I,J),
          2  NXTS(I,J),NXTF (I,J),AVGTM(I,J),AVGTMD(I,J),PROBSUC(I,J),
          3  TMLE(I,J),TMLN(I,J),ISJT(I,J),NXTJ(I,J),NXTJP(I,J), JAG(I,J)
        240 FORMAT (2X,I3,3X,A1,3X,A1,I5,F8.2,I4,I5,F9.3,F8.3,F7.3,F10.3,
          1F10.3,3I5, I7)
        245 J=J+1
            IF(J .GT. 2)  GO TO 252
            WRITE(6,2000)
       2000 FORMAT (1H1)
            GO TO 210
```

```
252 DO 258 K=1,2
255 READ (IN,256)  J,STRN(J),SPEED(J),TRAVA(J),PRB(J), JOT(J)
256 FORMAT (I1,4F10.0, I1)
    IF (J.EQ.0) GO TO 50
258 CONTINUE
    WRITE (IO,250)
250 FORMAT (1H1)
    WRITE (IO,260)  STRN,SPEED,TRAVA,PRO,JOT
260 FORMAT (5X, 17HSTRESS THRESHOLD=,2F11.3/16X,  6HSPEED=,2F11.3/
   2  8X,14HTIME ALLOTTED=,2F11.3/15X, 7HPERIOD=,2F11.3/17X,
   3 SHTYPE=; 2( I7, 4X))
    IF((JOT(1) + JOT(2)) .GT. 0 ) CALL RANITUN)
    RETURN
    END
```

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```
      SUBROUTINE  INPUT                                    CDC 6600 FTN V3.0-P243 OPT=1  -3/24/71  11.51.36.

      SYMBOLIC REFERENCE MAP

 ENTRY POINTS
     2  INPUT

 VARIABLES      SN  TYPE            RELOCATION
   1152  ADDSTR     REAL         ARRAY    B3               6  AFS       REAL       ARRAY    B4
      4  APS        REAL         ARRAY    B4            4545  ASTS      REAL       ARRAY    NEW
   2205  ATMU       REAL         ARRAY    NEW              0  ATU       REAL       ARRAY    B4
      2  ATW        REAL         ARRAY    B4            1154  AUGSTR    REAL       ARRAY    B3
  11311  AVGCOM     REAL         ARRAY    NEW           7020  AVGIN     REAL       ARRAY    B1
  10150  AVGTMD     REAL         ARRAY    B1            1156  COMES     REAL       ARRAY    B3
  11307  COMLAS     REAL         ARRAY    NEW             11  CWAIT     REAL       ARRAY    B2
  1244.  DFMAX      REAL         ARRAY    NEW           1110  LSS       REAL       ARRAY    B1
    764  MEAN       REAL         ARRAY    PLT            516  MOL       REAL
   3446  I          INTEGER               B3            5675  IASTS     INTEGER    ARRAY    NEW
   3415  IAVG       INTEGER      ARRAY    NEW              0  ICALL     INTEGER              E.P.
      4  ICHNG      INTEGER               NEW            636  ID1       INTEGER
    637  ID2        INTEGER                              640  ID3       INTEGER
    641  ID4        INTEGER                             2312  IFREQ     INTEGER    ARRAY    B3
     10  IFREQF     INTEGER      ARRAY    B4              22  IFREQL    INTEGER    ARRAY    B3
   3454  IGNORE     INTEGER               B3            3460  IN        INTEGER             B3
   3450  IND1       INTEGER               B3            3451  IND2      INTEGER             B3
   3452  IND3       INTEGER               B3            3453  IND4      INTEGER             B3
   3464  IND5       INTEGER               B3            3465  IND6      INTEGER             B3
   3461  IO         INTEGER               B3            3447  IP        INTEGER             B3
      5  IPKF       INTEGER      ARRAY    NEW           2260  IPREC     INTEGER    ARRAY    B1
      4  IRAND      INTEGER      ARRAY    B3           14712  ISJT      INTEGER    ARRAY    B1
     20  ISTRS      INTEGER      ARRAY    B3               0  ISUMF     INTEGER    ARRAY    NEW
      2  ISUMI      INTEGER      ARRAY    NEW              2  ITASK     INTEGER    ARRAY    B3
   3457  ITER       INTEGER               B3            3444  J         INTEGER             B3
   1130  JAG        INTEGER      ARRAY    RAMS          2310  JFLAG     INTEGER    ARRAY    B3
   2260  JOT        INTEGER      ARRAY    RAMS          3445  JP        INTEGER             B3
   2306  JPW        INTEGER      ARRAY    B3             645  K         INTEGER
    644  KH         INTEGER                              650  L         INTEGER
   3442  LST        INTEGER      ARRAY    B3             643  NINPC     INTEGER
      7  NRUN       INTEGER               B2           14710  NTASK     INTEGER    ARRAY    B1
   7027  NUMCOM     INTEGER      ARRAY    NEW             10  NUMIT     INTEGER             B1
    642  NUMRUN     INTEGER                                6  NUMTRL    INTEGER             B1
   5670  NXTF       INTEGER      ARRAY    B1           16042  NXTJ      INTEGER    ARRAY    B1
  17172  NXTJP      INTEGER      ARRAY    H1            4540  NXTS      INTEGER    ARRAY    B1
      0  OLPROB     REAL         ARRAY    RAMS          3455  PI        REAL                B3
  11300  PRBSUC     REAL         ARRAY    B1              15  PHD       REAL       ARRAY    B2
      0  PV1        REAL         ARRAY    PLT            536  PV2       REAL       ARRAY    PLT
      2  SPEED      REAL         ARRAY    R2             774  STABLE    REAL       ARRAY    PLT
   1614  STAX       REAL         ARRAY    PLT             14  STR       REAL       ARRAY    B3
      0  STRM       REAL         ARRAY    B2              16  STRS      REAL       ARRAY    H3
  10157  SUMCOM     REAL         ARRAY    NEW           1135  SUMTF     REAL       ARRAY    NEW
     13  SWAIT      REAL         ARRAY    B2             647  TES       REAL
     12  TIMF       REAL         ARRAY    R3               0  TITLE     REAL       ARRAY    ABCD
      4  TMAVA      REAL         ARRAY    B2            3410  TMBEG     REAL       ARRAY    B1
  12430  TMLE       REAL         ARRAY    H1           13560  TMLN      REAL       ARRAY    R1
      0  TMU        REAL         ARRAY    B3              17  TMUP      REAL       ARRAY    B1
     10  TOTTMI     REAL         ARRAY    R3            3462  TOTTMS    REAL       ARRAY    B3
```

```
     SUBROUTINE  INPUT                                   CDC 6600 FTN V3.0-P243 OPT=1  -3/24/71  11.51.36.

VARIABLES     SN  TYPE            RELOCATION
  7025  TSUMTF     REAL      ARRAY    NEW           646  FUN      REAL
  3456  TWOPI      REAL               B3              0  TYPE     REAL      ARRAY    B1
 12443  VGOAL      REAL      ARRAY    NEW             6  ARAND    REAL      ARRAY    B3

FILE NAMES         MODE
       TAPE5       FMT                TAPE6     FMT

EXTERNALS          TYPE   ARGS
       RAN                  1

STATEMENT LABELS
      0   2                                 21   50                           23   74
    517  75        FMT                      43   76                          521  100     FMT
    523 101        FMT  NO REFS              0  105      INACTIVE            527  110     FMT
      0 122                                  0  130      INACTIVE            240  145
    271 150                                274  151                          537  200     FMT
    307 210                                550  220   FMT                      0  235          INACTIVE
      0 230                                602  240   FMT                    427  245
    617 250        FMT                     436  252                             0  255          INACTIVE
    614 256        FMT                       0  258                          621  260     FMT
    525 1000       FMT                     612  2000  FMT

COMMON BLOCKS    LENGTH
       PLT         1000
       B1          8402
       B2            17
       B3          1044
       B4           600
       NEW         5413
       ARCO          12
       RAMS        1202

STATISTICS
  PROGRAM LENGTH     653B     427
   COMMON LENGTH   44114B   18508
```

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```
CRAMSB        SUBROUTINE RAM - RELIABILITY AND MAINTAIN ADJUSTMENT
              SUBROUTINE RAM

        C     THE PURPOSE OF THIS SUBROUTINE IS TO ADJUST THE TASK ELMMENT
        C     SUCCESS PROBABILITIES SUCH THAT THE MULTIPLICATIVE SUM OF ALL
        C     TASK ELEMENTS IN A PARTICULAR GROUP IS EQUAL TO A PREDETERMINED VALUE
        C     THIS VALUE IS GIVEN IN MATRIX SPOG-SUCCESS PROBABILITY OF GROUP

              COMMON /B1/ TYPE(300,2), ESS(300,2), IPREC(300,2), TMBEG(300,2),
             1 NXTS(300,2), NXTF(300,2), AVGTM(300,2), AVGTMD(300,2),
             2 PRBSUC(300,2), TMLE(300,2), TMLN(300,2), NTASK(2), ISJT(300,2),
             3 NXTJ(300,2), NXTJP(300,2)

              COMMON /B2/  STRM(2),SPEED(2),TMAVA(2),NUMTRL,NRUN,NUMIT,
             1 CWAIT(2),SWAIT(2),PRD(2),TMUP(2)

              COMMON/B3/ TMU(2)     ,ITASK(2)   ,IRAND(2)   ,XRAND(2)   ,
             2 TOTTMI(2),    TIME(2),        STR(2),        STRS(2),      ISTRS(2),
             3 IFREQL(300,2),ADDSTR(2),  AUGSTR(2),    COMES(300,2),JPW(2),
             4 JFLAG(2),     IFREQ(300,2),
             4 LST(2)     ,J         ,JP         ,I          ,IP        ,IND1
             5 IND2       ,IND3      ,IND4       ,IGNORE     ,PI        ,TWOPI
             6 ITER       ,IN        ,IO         ,TOTTMS(2)     ,IND5      ,IND6

              COMMON /RAMS/ OLPROB(300,2), JAG(300,2),  JOT(2)

              COMMON /SPEC/              NG(8,2), PG(8,2), TP(8,2),
             1 ICE(8,2), TNR(8,2), AID(8,2)

              DIMENSION SPOG(8,8)

              DATA SPOG / .82,  .78,  .73,  .88,  .74,  .55,  .92,  .74,
             2            .90,  .98,  .91,  .97,  .70,  .83,  .86,  .95,
             3            .94,  .92,  .87,  .93,  .78,  .86,  .96,  .97,
             4            .56,  .72,  .63,  .65,  .64,  .62,  .65,  .44,
             5            .41,  .30,  .97,  .91,  .38,  .32,  .91,  .56,
             6            .68,  .73,  .93,  .71,  .77,  .64,  .85,  .96,
             7            .74,  .72,  .87,  .44,  .88,  .94,  .93,  .53,
             8            .63,  .38,  .65,  .66,  .84,  .38,  .74,  .67/
        C   INITIALIZATION
              DO 7 J = 1,2
              DO 5 JA = 1,8
              NG(JA,J) = 0
              PG(JA,J) = 0.
              TP(JA,J) = 0.
              ICE(JA,J) = 0
              TNR(JA,J) = 0.
              AID(JA,J) = 0.
            5 CONTINUE
            7 CONTINUE
              J = 1
              I = 1
              IOK = 0
```

```
   10 CONTINUE
      JA = JAA(I,J)
      IF(JA .LE. 0 .OR. JA .GT. 8) GO TO 20
      NG(JA,J) = NG(JA,J) + 1
      IF( PG(JA,J) .LE. 0. ) GO TO 15
      PG(JA,J) = PG(JA,J) * PRBSUC(I,J)
      GO TO 20
   15 PG(JA,J) = PRBSUC(I,J)
   20 CONTINUE
      IF(PRBSUC(I,J) .LE. .5 .AND. NXTF(I,J) .NE. I) GO TO 25
      I = NXTS(I,J)
      GO TO 30
   25 I = NXTF(I,J)
   30 CONTINUE
      IF(I.GT. 0 ) GO TO 10
      IF(J .EQ. 2) GO TO 40
      J = 2
      I = 1
      GO TO 10
   40 CONTINUE
      DO 62 J = 1,2
      JT = JOT(J)
      DO 60 JA = 1,8
      IF(NG(JA,J) - 1 ) 52,60, 56
   52 ICE(JA,J) = 1
      IOK = IOK + 1
      GO TO 60
   56 CONTINUE
      TEST = ABS( SPOG(JA,JT) - PG(JA,J))
      IF(TEST .GE. .01 ) GO TO 58
      ICE(JA, J) = 1
      IOK = IOK + 1
      GO TO 60
   58 CONTINUE
      FN = NG(JA,J)
      TNN(JA,J) = SPOG(JA,JT)**(1. / FN)
   60 CONTINUE
   62 CONTINUE
      DO 70 J = 1,2
      JT= JOT(J)
      IF(JT .LE. 0 ) GO TO 70
      WRITE(10, 1000) J
 1000 FORMAT(1H1, 45H ORIGINAL DATA BEFORE ADJUSTMENT FOR OPERATOR,
     1 I5//5X, 2HJA, 5X, 2HNG, 5X, 2HPG,5X, 2HSP, 5X, 2HOK)
      DO 65 JA = 1,8
```

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SUBROUTINE RAM CDC 6600 FTN V3.0-P243 OPT=1 3/24/71 11.51.36.

```
      WRITE(IO, 1010 ) JA, NG(JA,J), PG(JA,J), SPOG(JA,JT), ICE(JA,J)
 1010 FORMAT(1H , I6, I7, F7.3, F7.2, I7)
   65 CONTINUE
   70 CONTINUE
      IF(IOK .GE. 16 ) GO TO 300
   80 CONTINUE
      J = 1
      I = 1
      JT = JOT(J)
   90 CONTINUE
      JA = JAG(I,J)
      IF( JA .LE. 0 .OR. JA .GT. 8 ) GO TO 100
      IF(ICE(JA,J) .EQ. 1 ) GO TO 100
      IF(NG(JA,J) .NE. 1 ) GO TO 95
      PRBSUC(I,J) = SPOG(JA,JT)
      ICE(JA,J) = 1
      IOK = IOK + 1
      GO TO 100
   95 AID(JA,J) = AID(JA,J) + (TNR(JA,J) - PRBSUC(I,J))
      TP(JA,J) = TP(JA,J) + (1. - PRBSUC(I,J))
      PG(JA,J) = 0

  100 CONTINUE
      IF(PRBSUC(I,J) .LE. .5 .AND. NXTF(I,J) .NE. 1) GO TO 110
      I = NXTS(I,J)
      GO TO 120
  110 I = NXTF(I,J)

  120 CONTINUE
      IF(I .GT. 0 ) GO TO 90
      IF(J .EQ. 2 ) GO TO 130
      J = 2
      I = 1
      JT = JOT(J)
      GO TO 90

  130 CONTINUE
      J = 1
      I = 1
      JT = JOT(J)
  140 CONTINUE
      JA = JAG(I,J)
      IF( JA .LE. 0 .OR. JA .GT. 8 ) GO TO 150
      IF( ICE(JA,J) .EQ. 1 ) GO TO 150
      PRBSUC(I,J) = PRBSUC(I,J) + ( 1. - PRBSUC(I,J)) *
     1  (AID(JA,J) / TP(JA,J))
      IF( PG(JA,J) .LE. 0.) GO TO 145
      PG(JA,J) = PG(JA,J) * PRBSUC(I,J)
      GO TO 150
  145 PG(JA,J) = PRBSUC(I,J)

  150 CONTINUE
      IF(PRBSUC(I,J) .LE. .5 .AND. NXTF(I,J) .NE. 1) GO TO 160
      I = NXTS(I,J)
```

```
      GO TO 170
  140 I = NXTF(I,J)
  170 CONTINUE
      IF(I .GT. 0 ) GO TO 140
      IF(J .EQ. 2 ) GO TO 180
      J = 2
      I = 1
      JT = JOT(J)
      GO TO 140
  180 CONTINUE
      DO 210 J = 1,2
      JT = JOT(J)
      DO 200 JA = 1,8
      IF(ICE(JA,J) .EQ. 1 ) GO TO 190
      TEST = ABS( SPOG(JA,JT) - PG(JA,J))
      IF(TEST .GE. .01 ) GO TO 190
      ICE(JA,J) = 1
      IOK = IOK + 1
  190 CONTINUE
  200 CONTINUE
  210 CONTINUE
      IF( IOK .GE. 16 ) GO TO 300
      DO 220 J = 1,2
      DO 220 JA = 1,8
      AID(JA,J) = 0.
      TP(JA,J) = 0.
  220 CONTINUE
      GO TO 80
  300 CONTINUE
      DO 320 J = 1,2
      JT = JOT(J)
      IF( JT .LE. 0 ) GO TO 320
      WRITE( IO, 1020) J
 1020 FORMAT(1H1, 25HREVISED DATA FOR OPERATOR, I4//X,
     1 47HTASK-EL  GROUP  N-GRP  GRPSUC  OLDPROB  NEWPROB)
      N = NTASK(J)
      DO 310 I = 1,N
      JA = JAG(I,J)
      IF(JA .LE. 0 .OR. JA .GT. 8 ) GO TO 305
      WRITE(IO,1030) I, JA, NG(JA,J), SPOG(JA,J),OLPROB(I,J),PRBSUC(I,J)
 1030 FORMAT(1H , I5, I8, I7, F8.2, F10.3, F8.3)
      GO TO 310
  305 WRITE(IO,1040) I, JA, OLPROB(I,J), PRBSUC(I,J)
 1040 FORMAT(1H , I5, I8, 15X, F10.3, F8.3)
  310 CONTINUE
  320 CONTINUE
      RETURN
      END
```

```
     SUBROUTINE  RAM                              CDC 6600 FTN V3.0-P243 OPT=1  03/24/71  11.51.36.

CARD NO.  SEVERITY          DIAGNOSTIC
--------------------------------------------------------------------------------------------
   204       I     53CD 204 X-FIELD PRECEDED BY A BLANK. 1X ASSUMED
```

```
SUBROUTINE  RAM                                   CDC 6600 FTN V3.0-P243 OPT=1  ^3/24/71  11.51.36.

     SYMBOLIC REFERENCE MAP

ENTRY POINTS
     1  RAM

VARIABLES      SN  TYPE             RELOCATION
  1152  ADDSTR    REAL       ARRAY   B3            120  AID       REAL       ARRAY   SPEC
  1154  AUGSTR    REAL       ARRAY   B3           7020  AVGTM     REAL       ARRAY   B1
 10150  AVGTMD    REAL       ARRAY   B1           1156  COMES     REAL       ARRAY   B3
    11  CWAIT     REAL       ARRAY   B2           1130  ESS       REAL       ARRAY   B1
   633  FN        REAL                            3446  I         INTEGER            B3
    60  ICE       INTEGER    ARRAY   SPEC         2312  IFREQ     INTEGER    ARRAY   B3
    22  IFREQL    INTEGER    ARRAY   B3           3454  IGNORE    INTEGER            B3
  3460  IN        INTEGER            B3           3450  IND1      INTEGER            B3
  3451  IND2      INTEGER            B3           3452  IND3      INTEGER            B3
  3453  IND4      INTEGER            B3           3464  IND5      INTEGER            B3
  3465  IND6      INTEGER            B3           3461  IO        INTEGER            B3
   630  IOK       INTEGER                         3447  IP        INTEGER            B3
  2260  IPREC     INTEGER    ARRAY   B1              4  IRAND     INTEGER    ARRAY   B3
 14712  ISJT      INTEGER    ARRAY   B1             20  ISTRS     INTEGER    ARRAY   B3
     2  ITASK     INTEGER    ARRAY   B3           3457  ITER      INTEGER            B3
  3444  J         INTEGER            B3            627  JA        INTEGER
  1130  JAG       INTEGER    ARRAY   RAMS         2310  JFLAG     INTEGER    ARRAY   B3
  2260  JOT       INTEGER    ARRAY   RAMS         3445  JP        INTEGER            B3
  2306  JPW       INTEGER    ARRAY   B3            631  JT        INTEGER
  3442  LST       INTEGER    ARRAY   B3            634  N         INTEGER
     0  NB        INTEGER    ARRAY   SPEC            7  NRUN      INTEGER            B2
 14710  NTASK     INTEGER    ARRAY   B1             10  NUMIT     INTEGER            B2
     6  NUMTRL    INTEGER            B2           5670  NXTF      INTEGER    ARRAY   B1
 16042  NXTJ      INTEGER    ARRAY   B1          17172  NXTJP     INTEGER    ARRAY   B1
  4540  NXTS      INTEGER    ARRAY   B1              0  ULPROB    REAL       ARRAY   RAMS
    20  PG        REAL       ARRAY   SPEC         3455  PI        REAL               B3
 11300  PRBSUC    REAL       ARRAY   B1             15  PRD       REAL       ARRAY   B1
     2  SPEED     REAL       ARRAY   B2            635  SPOG      REAL       ARRAY
    14  STR       REAL       ARRAY   B3              0  STRM      REAL       ARRAY   B3
    16  STRS      REAL       ARRAY   B3             13  SWAIT     REAL       ARRAY   B3
   632  TEST      REAL                              12  TIME      REAL       ARRAY   B3
     4  TMAVA     REAL       ARRAY   B2           3410  TMBEG     REAL       ARRAY   B1
 12430  TMLE      REAL       ARRAY   B1          13560  TMEN      REAL       ARRAY   B1
     0  TMU       REAL       ARRAY   B3             17  TMUP      REAL       ARRAY   B2
   100  TNR       REAL       ARRAY   SPEC           10  TOTTMI    REAL       ARRAY   B3
  3462  TOTTMS    REAL       ARRAY   B3             40  TP        REAL       ARRAY   SPEC
  3456  TWOPI     REAL               B3              0  TYPE      REAL       ARRAY   B1
     6  XRAND     REAL       ARRAY   B3

INLINE FUNCTIONS   TYPE   ARGS
       ABS         REAL     1  INTRIN

STATEMENT LABELS
     0  5                          0  7                          20  10
    45  15                        52  20                         65  28
    71  30                       100  40                          0  53      INACTIVE
   115  56                       132  58                        144  60
     0  62                         0  65                        215  70
```

```
          SUBROUTINE   RAM                                     CDC 6600 FTN V3.0-P243 OPT=1   -3/24/71  11.51.36.
   STATEMENT LABELS
      222   80
      274   100                         225   90                             256   95
      324   130                         307   110                            313   120
      372   150                         327   140                            365   145
      422   180                         405   160                            411   170
        0   210                         442   190                              0   200
      536   305                           0   220                            462   300
      504   1000     FMT                556   310                            561   320
      614   1030     FMT                576   1010     FMT                   602   1020     FMT
                                        620   1040     FMT
   COMMON BLOCKS     LENGTH
             B1        8402
             B2          17
             B3        1000
             RAWS      1702
             SPEC        96

   STATISTICS
      PROGRAM LENGTH     7350     477
      COMMON LENGTH    264530   11563
```

```
      FUNCTION DEV(D)
C
      DIMENSION XTAB(17),YTAB(17)
     1,         SCALE(1),AMPY(1),BASE(1)
C
C
      INTEGER BASE,D
C
C
      DATA     (XTAB(I),I=1,17)/0.0,0.1554,0.2500,0.3159,0.3646,0.4032,
     1 0.4192,0.4332,0.4452,0.4554,0.4641,0.4713,0.4772,0.4821,0.4878,
     2 0.4938,0.5000/
      DATA     (YTAB(I),I=1,17)/0.0,0.4,0.7,0.9,1.1,1.3,1.4,1.5,1.6,1.7,
     1                          1.8,1.9,2.0,2.1,2.25,2.50,4.0/
      DATA SCALE,AMPY,BASE/8.388608E06,1.953125E06,1270579/
C
C
C
      HOLD = FLOAT(BASE)*AMPY
      BASE = IFIX(HOLD) .AND. 37777777B
      A1 = (FLOAT(BASE)/SCALE) - 0.5
      A2 = ABS(A1)
      DO 50   I=1,17
      IF(A2 .LT. XTAB(I)) GO TO 70
   50 CONTINUE
      DEV = 0.0
      RETURN
   70 TEMP = YTAB(I-1) + ((YTAB(I) - YTAB(I-1))*((A2 - XTAB(I-1))/
     1        (XTAB(I) - XTAB(I-1))))
      DEV = TEMP
      IF(A1 .GE. 0.0) GO TO 90
      DEV = -TEMP
   90 RETURN
C
C
      ENTRY SETBASE
      BASE = D
      RETURN
      END
```

```
CARD NO.  SEVERITY          DIAGNOSTIC

   19        I      BASE     ARRAY NAME OPERAND NOT SUBSCRIPTED. FIRST ELEMENT WILL BE USED
   19        I      AMPY     ARRAY NAME OPERAND NOT SUBSCRIPTED. FIRST ELEMENT WILL BE USED
   20        I      BASE     ARRAY NAME OPERAND NOT SUBSCRIPTED. FIRST ELEMENT WILL BE USED
   21        I      BASE     ARRAY NAME OPERAND NOT SUBSCRIPTED. FIRST ELEMENT WILL BE USED
   21        I      SCALF    ARRAY NAME OPERAND NOT SUBSCRIPTED. FIRST ELEMENT WILL BE USED
   37        I      BASE     ARRAY NAME OPERAND NOT SUBSCRIPTED. FIRST ELEMENT WILL BE USED
```

```
FUNCTION    DEV                                    CDC 6600 FTN V3.0-P243 OPT=1  -3/24/71  11.51.36.

SYMBOLIC REFERENCE MAP

ENTRY POINTS
    2  DEV              45  SETBASE

VARIABLES      SN  TYPE            RELOCATION
  134  AMPY          REAL        ARRAY                      65  A1          REAL
   66  A2            REAL                                  135  BASE        INTEGER     ARRAY
    0  D             INTEGER              F.P.              63  DEV         REAL
   64  HOLD          REAL                                   67  I           INTEGER
  133  SCALE         REAL        ARRAY                      70  TEMP        REAL
   71  XTAB          REAL        ARRAY                     112  YTAB        REAL        ARRAY

INLINE FUNCTIONS   TYPE    ARGS
      ABS          REAL      1  INTRIN                      FLOAT       REAL        1  INTRIN
      IFIX         INTEGER   1  INTRIN

STATEMENT LABELS
    0  50                          27  70                                  42  90

STATISTICS
  PROGRAM LENGTH     136B      94
```

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```
CORE MAP  11.52.00.  NORMAL           CONTROL                                                   000100    004313    000000    000000
       ---TIME---LOAD MODE --L1--L2----TYPE-------------------USER-------CALL-------------WA LOAD--LWA LOAD--BLNK COMM--LENGTH--
       FWA LOADER  073774  FWA TABLES  070041
       -PROGRAM-----ADDRESS-                       --LABELLED---COMMON--
       PAR4          042553                          PLT           000100
                                                     W1            002060
                                                     B2            022402
                                                     B3            022423
                                                     W4            026111
                                                     NEW           027251
                                                     NEWF          041716
                                                     ARCD          042537
       RESET         051576                          B1            002060
                                                     B2            022402
                                                     B3            022423
                                                     B4            026111
                                                     NEW           027251
       INPUT         054137                          PLT           000100
                                                     B1            002060
                                                     B2            022402
                                                     W3            022423
                                                     W4            026111
                                                     NEW           027251
                                                     ARCD          042537
                                                     RANS          051655
       RAN           055152                          B1            002060
                                                     B2            022402
                                                     B3            022423
                                                     RANS          051655
                                                     SPEC          055012
       DEV           056107
       GETBA         056245
       SIO$          056264
       ACGOER$       057630
       INPUTC$       057643
       KODER$        057761
       KRAKER$       061355
       OUTPTC$       063047
       ALNLOGE       063143
       EXPE          063202
       RANDOME       063247
       RANF$         063251
       XTOYE         063256
       SYSTEM$       063265
       --ENTRY-----ADDRESS-                                      REFFRENCES
       PAR4          046625
       INPUT=        042553
       OUTPUT=       044575
       TAPE5=        042553        INPUT       054162

       TAPE6=        044575        INPUT       054571

       RESET         051600        PAR4        046730     046725     046707

       INPUT         054141        PAR4        046713     046673
```

RAN	055153	INPUT	054650						
DEV	056111	PAR4	047333	047146					
SETBASE	056154	PAR4	046701						
GFIRA	056246	SIO$	056537						
CIOI.	057327								
RCLI.	057350	SYSTEMS	064045						
DAT.	056266	INPUTC$	057676	057740	057746	057754			
		KODERS	060112	060671					
		KRAKERS	061503	062112	062113	062174	062202		
		OUTPTC$	063070	063122	063132				
		SYSTEMS	063556	063601	063610	063710	063721	063722	063744
			063756	063775					
SIO.CTL	056514	SYSTEMS	063776	063716	063665	064027	063672	063711	063350
INITL.	056535	INPUTC$	057705						
		OUTPTC$	063103						
		SYSTEMS	064025						
SIO.	056601	INPUTC$	057750						
		OUTPTC$	063126						
		SYSTEMS	063670	063776	063714				
SIO.END	057302	SYSTEMS	064042						
OPEN.	057357	SYSTEMS	064014						
RDPRU.	057420								
BKSPRU.	057435								
ADVIN.	057442	SYSTEMS	064041						
POSFI.	057470								
MVWDS.	057615								
ACGOER.	057631	PAR4	047260	047226	047212				
IPUTCI.	057703	PAR4	046627						
		INPUT	054600	054250	054241	054206	054163		
INPUTC.	057720	PAR4	046632	046631					
		INPUT	054615	054614	054612	054610	054606	054604	054602
			054351	054350	054344	054340	054334	054330	054324
			054320	054314	054310	054304	054300	054274	054270
			054264	054260	054254	054252	054244	054243	054231
			054230	054226	054224	054222	054220	054216	054214
			054212	054210	054176	054175	054173	054171	054167
			054165						
KODER.	057762	OUTPTC$	063076	063110					

KRAKER.	061356	INPUTCS	057730	057701	057724				
FRRSETS	062066								
OPUTCI.	063100	PAR4	051025	051013	050750	050665	050660	050635	050567
			050547	050515	050506	050470	050371	050300	050044
			050002	047066	046737				
		INPUT	054631	054625	054572	054463	054450	054435	
		RAM	055712	055661	055642	055340	055331		
OUTPTC.	063107	PAR4	051032	051031	051027	051020	051017	051015	050777
			050776	050774	050772	050770	050766	050764	050762
			050760	050756	050754	050752	050666	050663	050662
			050656	050655	050653	050651	050647	050645	050643
			050641	050637	050612	050611	050607	050605	050603
			050601	050577	050575	050573	050571	050550	050542
			050541	050537	050535	050533	050531	050527	050525
			050476	050474	050472	050352	050351	050347	050345
			050343	050341	050337	050335	050333	050331	050327
			050325	050323	050313	050312	050310	050306	050304
			050302	050103	050102	050076	050074	050072	050070
			050066	050064	050062	050060	050054	050050	050046
			050041	050040	050036	050032	050030	050026	050024
			050022	050020	050016	050014	050010	050004	047067
			046746	046745	046743	046741			
		INPUT	054644	054643	054641	054637	054635	054633	054626
			054573	054562	054561	054555	054551	054545	054541
			054535	054531	054525	054521	054515	054511	054505
			054501	054475	054471	054465	054453	054452	054444
			054443	054441	054437				
		RAM	055727	055726	055722	055716	055714	055706	055705
			055701	055675	055671	055665	055663	055645	055644
			055363	055362	055356	055352	055346	055342	055334
			055333						
ALOG.	063143	XTOYE	063256						
ALOG10.	063165								
EXP.	063203	XTOYE	063260						
RANDOM.	063247	RANFS	063253						
RANMLT.	063250								
RANFS	063252	PAR4	047502	047011	046772	046675			
XTOY.	063261								
XTOYS.	063261	RAM	055312						
QRNTRY.	063271	PAR4	046625						
END.	063347	PAR4	051055						
EXITS	063372								
STOP.	063400	PAR4	047071						
		INPUT	054236						

```
ARNORM.     063411         ACGOERS     057634
                           INPUTCS     057723
                           KODERS      061051
                           KRAKERS     062372     062464
                           OUTPTCS     063142
SYSTEME     063430
SYSTEMS     063454
SYSTEM.     063460
SYSTEM:     063512
                           ACGOERS     057633
                           INPUTCS     057722
                           KODERS      061035     061046     061050     061020
                           KRAKERS     062206     062221     062321     062345     062407     062433     062450
                                       062461
                           OUTPTCS     063141
SYS1:       063700         KRAKERS     062133     062323     062140
SYS2:       063674         KRAKERS     062327     062463     062313
LOT:        064105         KRAKERS     062325     062331
DRGFET.     064125
----UNSATISFIED EXTERNALS-----                              REFERENCES
```

TASK NUMBER 1
NUMBER OF RUNS 1 NUMBER OF ITERATIONS 5

TASK DATA FOR OPERATOR 1

TASK NO	TASK TYPE	NON ESS	PRECEDENCE TASK	PRECEDENCE TIME	NEXT-TASK SUC	NEXT-TASK FAIL	AVERAGE TIME	TIME DEV	PROB. SUC	TIME REMAINING ESS	TIME REMAINING NON-ESS	SPEC. CODE	JUMP OP1	TASK OP2	JAG
1			-0	-0.00	2	1	2.710	1.060	.970	1070.640	0.000	-0	-0	-0	7
2			-0	-0.00	3	2	8.780	1.250	.970	1067.930	0.000	-0	-0	-0	7
3			-0	-0.00	4	3	2.710	1.060	.970	1059.150	0.000	-0	-0	-0	7
4			-0	-0.00	5	4	3.000	1.000	.980	1056.440	0.000	-0	-0	-0	7
5			-0	-0.00	6	5	2.710	1.060	.970	1053.440	0.000	-0	-0	-0	7
6			-0	-0.00	7	6	3.000	1.000	.980	1050.730	0.000	-0	-0	-0	7
7			-0	-0.00	8	7	2.710	1.060	.970	1047.730	0.000	-0	-0	-0	7
8			-0	-0.00	9	8	8.780	1.000	.980	1045.020	0.000	-0	-0	-0	7
9			-0	-0.00	10	9	150.000	60.000	.500	1036.240	0.000	-0	-0	-0	9
10			-0	-0.00	11	10	14.340	1.640	.890	886.240	0.000	-0	-0	-0	7
11			-0	-0.00	44	11	1.200	.400	.990	871.900	0.000	-0	-0	-0	7
12			-0	-0.00	13	12	150.000	50.000	.990	870.700	0.000	-0	-0	-0	9
13			-0	-0.00	14	13	2.330	.650	.990	720.700	0.000	-0	-0	-0	7
14			-0	-0.00	15	14	28.000	5.820	.980	718.370	0.000	-0	-0	-0	-0
15			-0	-0.00	16	15	2.330	.650	.990	690.370	0.000	-0	-0	-0	7
16			-0	-0.00	17	16	115.240	28.420	.940	688.040	0.000	-0	-0	-0	-0
17			-0	-0.00	18	17	1.100	.330	.990	572.800	0.000	-0	-0	-0	-0
18			-0	-0.00	19	18	65.380	21.760	.970	571.700	0.000	-0	-0	-0	-0
19			-0	-0.00	20	19	6.760	2.250	.980	506.320	0.000	-0	-0	-0	-0
20			-0	-0.00	45	20	60.120	20.110	.970	499.560	0.000	-0	-0	-0	-0
21			-0	-0.00	22	21	2.330	.650	.990	439.440	0.000	-0	-0	-0	7
22			-0	-0.00	23	22	28.000	5.820	.980	437.110	0.000	-0	-0	-0	-0
23			-0	-0.00	24	23	2.330	.650	.990	409.110	0.000	-0	-0	-0	7
24			-0	-0.00	25	24	14.320	4.770	.980	406.780	0.000	-0	-0	-0	7
25			-0	-0.00	26	25	8.600	3.000	.930	392.460	0.000	-0	-0	-0	7
26			-0	-0.00	27	26	2.710	1.060	.970	383.860	0.000	-0	-0	-0	7
27			-0	-0.00	28	27	8.780	1.250	.970	381.150	0.000	-0	-0	-0	7
28			-0	-0.00	29	28	16.720	5.540	.920	372.370	0.000	-0	-0	-0	7
29			-0	-0.00	30	29	4.060	1.350	.990	355.650	0.000	-0	-0	-0	7
30			-0	-0.00	31	30	2.710	1.060	.970	351.590	0.000	-0	-0	-0	7
31			-0	-0.00	32	31	3.000	1.250	.970	348.880	0.000	-0	-0	-0	7
32			-0	-0.00	33	32	16.720	5.540	.920	345.880	0.000	-0	-0	-0	7
33			-0	-0.00	34	33	4.060	1.350	.990	329.160	0.000	-0	-0	-0	7
34			-0	-0.00	35	34	2.710	1.060	.970	325.100	0.000	-0	-0	-0	7
35			-0	-0.00	36	35	3.000	.025	.970	322.390	0.000	-0	-0	-0	7
36			-0	-0.00	37	36	16.720	5.540	.920	319.390	0.000	-0	-0	-0	7
37			-0	-0.00	38	37	4.060	1.350	.990	302.670	0.000	-0	-0	-0	7
38			-0	-0.00	39	38	2.710	1.060	.970	298.610	0.000	-0	-0	-0	7
39			-0	-0.00	40	39	8.780	1.250	.970	295.900	0.000	-0	-0	-0	7
40			-0	-0.00	41	40	16.720	5.540	.920	287.120	0.000	-0	-0	-0	7
41			-0	-0.00	42	41	4.060	1.350	.990	270.400	0.000	-0	-0	-0	7
42			-0	-0.00	43	42	1.100	.330	.990	266.340	0.000	-0	-0	-0	-0
43			-0	-0.00	47	43	115.240	28.420	.940	265.240	0.000	-0	-0	-0	-0
44	D		-0	-0.00	12	1	-0.000	-0.000	.700	150.000	0.000	-0	-0	-0	1
45	D		-0	-0.00	46	1	-0.000	-0.000	.950	150.000	0.000	-0	-0	-0	1

46	D		-0	-0.00	21	12	-0.000	-0.000	.950	150.000	0.000	-0	-0	-0	1
47	D		-0	-0.00	48	1	-0.000	-0.000	.800	150.000	0.000	-0	-0	-0	1
48	D		-0	-0.00	49	12	-0.000	-0.000	.950	150.000	0.000	-0	-0	-0	1
49	D		-0	-0.00	50	21	-0.000	-0.000	.950	150.000	0.000	-0	-0	-0	1
50			-0	-0.00	-0	50	150.000	50.000	.990	150.000	0.000	-0	-0	-0	9

TASK DATA FOR OPERATOR 2

TASK NO	TASK TYPE	NON ESS	PRECEDENCE TASK	PRECEDENCE TIME	NEXT-TASK SUC	NEXT-TASK FAIL	AVERAGE TIME	TIME DEV	PROB. SUC	TIME REMAINING ESS	TIME REMAINING NON-ESS	SPEC. CODE	JUMP OP1	TASK OP2	JAG
1			-0	-0.00	-0	1	-0.000	-0.000	1.000	0.000	0.000	-0	-0	-0	-0

STRESS THRESHOLD=	2.300	2.300
SPEED=	1.000	1.000
TIME ALLOTTED=	10000.000	10000.000
PERIOD=	-0.000	-0.000
TYPE-	1	-0

ORIGINAL DATA BEFORE ADJUSTMENT FOR OPERATOR 1

JA	NG	PG	SP	OK
1	6	.456	.62	0
2	0	0.000	.78	1
3	0	0.000	.73	1
4	0	0.000	.60	1
5	0	0.000	.74	1
6	0	0.000	.55	1
7	32	.336	.92	0
8	0	0.000	.74	1

REVISED DATA FOR OPERATOR 1

TASK-EL	GROUP	N-GRP	GRPSUC	OLDPROB	NEWPROB
1	7	32	.92	.970	.998
2	7	32	.92	.970	.998
3	7	32	.92	.970	.998
4	7	32	.92	.980	.998
5	7	32	.92	.970	.998
6	7	32	.92	.980	.998
7	7	32	.92	.970	.998
8	7	32	.92	.980	.998
9	9			.500	.500
10	7	32	.92	.890	.991
11	7	32	.92	.990	.999
12	9			.990	.990
13	7	32	.92	.990	.999
14	-0			.980	.980
15	7	32	.92	.990	.999
16	-0			.940	.940
17	-0			.990	.990
18	-0			.970	.970
19	-0			.980	.980
20	-0			.970	.970
21	7	32	.92	.990	.999
22	-0			.980	.980
23	7	32	.92	.990	.999
24	7	32	.92	.980	.998
25	7	32	.92	.930	.995
26	7	32	.92	.970	.998
27	7	32	.92	.970	.998
28	7	32	.92	.920	.994
29	7	32	.92	.990	.999
30	7	32	.92	.970	.998
31	7	32	.92	.970	.998
32	7	32	.92	.920	.994
33	7	32	.92	.990	.999
34	7	32	.92	.970	.998
35	7	32	.92	.970	.998
36	7	32	.92	.920	.994
37	7	32	.92	.990	.999
38	7	32	.92	.970	.998
39	7	32	.92	.970	.998
40	7	32	.92	.920	.994
41	7	32	.92	.990	.999
42	-0			.990	.990
43	-0			.940	.940
44	1	6	.62	.700	.803
45	1	6	.62	.950	.967
46	1	6	.62	.950	.967
47	1	6	.62	.800	.869
48	1	6	.62	.950	.967
49	1	6	.62	.950	.967
50	9			.990	.998

DETAIL OUTPUT OF ITERATION 1 RUN 1 TASK 1

OPERATOR 1

TASK NO	TASK TYPE	NON ESS	STRESS IND	STRESS TOT	WAIT	TASK	CUM	SFI	COMES
1			1.00	1.00	0.00	1.20	1.20		0.00
2			1.00	1.00	0.00	9.13	10.34		0.00
3			1.00	1.00	0.00	4.58	14.92		0.00
4			1.00	1.00	0.00	4.64	19.56		0.00
5			1.00	1.00	0.00	3.24	22.79		0.00
6			1.00	1.00	0.00	4.47	27.27		0.00
7			1.00	1.00	0.00	.75	28.02		0.00
8			1.00	1.00	0.00	8.45	36.47		0.00
9			1.00	1.00	0.00	123.62	160.10		0.00
10			1.00	1.00	0.00	13.94	174.03		0.00
11			1.00	1.00	0.00	1.17	175.20		0.00
44	D		1.00	1.00	0.00	0.00	175.20		*9587.58
12			1.00	1.00	0.00	87.85	263.05		0.00
13			1.00	1.00	0.00	1.99	265.04		0.00
14			1.00	1.00	0.00	32.65	297.68		0.00
15			1.00	1.00	0.00	2.25	299.94		0.00
16			1.00	1.00	0.00	70.16	370.10		0.00
17			1.00	1.00	0.00	.75	370.85		0.00
18			1.00	1.00	0.00	27.12	397.96		0.00
19			1.00	1.00	0.00	6.18	404.15		0.00
20			1.00	1.00	0.00	85.70	489.84		0.00
45	D		1.00	1.00	0.00	0.00	489.84		*0300.10
46	D		1.00	1.00	0.00	0.00	489.84		.00
21			1.00	1.00	0.00	2.15	491.99		0.00
22			1.00	1.00	0.00	38.39	530.39		0.00
23			1.00	1.00	0.00	1.68	532.06		0.00
24			1.00	1.00	0.00	16.97	549.03		0.00
25			1.00	1.00	0.00	20.12	569.15		0.00
26			1.00	1.00	0.00	3.67	572.82		0.00
27			1.00	1.00	0.00	7.44	580.26		0.00
28			1.00	1.00	0.00	17.98	598.24		0.00
29			1.00	1.00	0.00	2.79	601.03		0.00
30			1.00	1.00	0.00	4.43	605.46		0.00
31			1.00	1.00	0.00	2.80	608.26		0.00
32			1.00	1.00	0.00	13.56	621.82		0.00
33			1.00	1.00	0.00	4.56	626.38		0.00
34			1.00	1.00	0.00	2.47	628.85		0.00
35			1.00	1.00	0.00	3.04	631.89		0.00
36			1.00	1.00	0.00	21.90	653.79		0.00
37			1.00	1.00	0.00	4.97	658.76		0.00
38			1.00	1.00	0.00	2.99	661.76		0.00
39			1.00	1.00	0.00	8.73	670.49		0.00
40			1.00	1.00	0.00	10.27	680.75		0.00
41			1.00	1.00	0.00	4.34	685.10		0.00
42			1.00	1.00	0.00	1.48	686.58		0.00
43			1.00	1.00	0.00	158.90	845.48		0.00
47	D		1.00	1.00	0.00	0.00	845.48	F	.00

OPERATOR 2

TASK NO	TASK TYPE	NON ESS	STRESS IND	STRESS TOT	WAIT	TASK	CUM	SFI	COMES
1			1.00	1.00	0.00	.75	.75		0.00

1		1.00	1.00	0.00	3.05	848.53		0.00
2		1.00	1.00	0.00	7.11	855.64		0.00
3		1.00	1.00	0.00	1.69	857.33		0.00
4		1.00	1.00	0.00	2.65	859.97		0.00
5		1.00	1.00	0.00	4.23	864.21		0.00
6		1.00	1.00	0.00	2.24	866.45		0.00
7		1.00	1.00	0.00	3.07	869.52		0.00
8		1.00	1.00	0.00	7.63	877.14		0.00
9		1.00	1.00	0.00	132.34	1009.48	F	0.00
9		1.00	1.00	0.00	48.29	1057.78	F	0.00
9		1.00	1.00	0.00	110.50	1168.28	F	0.00
9		1.00	1.00	0.00	21.35	1189.63		0.00
10		1.00	1.00	0.00	15.57	1205.20		0.00
11		1.00	1.00	0.00	1.63	1206.83		0.00
44	D	1.00	1.00	0.00	0.00	1206.83	F	*9587.58
1		1.00	1.00	0.00	2.67	1209.50		0.00
2		1.00	1.00	0.00	8.41	1217.91		0.00
3		1.00	1.00	0.00	3.93	1221.85		0.00
4		1.00	1.00	0.00	2.57	1224.42		0.00
5		1.00	1.00	0.00	3.84	1228.25		0.00
6		1.00	1.00	0.00	2.35	1230.61		0.00
7		1.00	1.00	0.00	1.49	1232.10		0.00
8		1.00	1.00	0.00	9.14	1241.25		0.00
9		1.00	1.00	0.00	166.93	1408.18	F	0.00
9		1.00	1.00	0.00	145.80	1553.97	F	0.00
9		1.00	1.00	0.00	107.02	1660.99	F	0.00
9		1.00	1.00	0.00	159.07	1820.06	F	0.00
9		1.00	1.00	0.00	123.26	1943.32		0.00
10		1.00	1.00	0.00	15.65	1958.97		0.00
11		1.00	1.00	0.00	1.56	1960.53		0.00
44	D	1.00	1.00	0.00	0.00	1960.53	F	*9587.58
1		1.00	1.00	0.00	3.01	1963.54		0.00
2		1.00	1.00	0.00	8.96	1972.50		0.00
3		1.00	1.00	0.00	.75	1973.25		0.00
4		1.00	1.00	0.00	5.45	1978.70		0.00
5		1.00	1.00	0.00	1.77	1980.48		0.00
6		1.00	1.00	0.00	2.78	1983.26		0.00
7		1.00	1.00	0.00	1.65	1984.91		0.00
8		1.00	1.00	0.00	7.12	1992.03		0.00
9		1.00	1.00	0.00	177.49	2169.52	F	0.00
9		1.00	1.00	0.00	109.04	2278.56	F	0.00
9		1.00	1.00	0.00	153.00	2431.55	F	0.00
9		1.00	1.00	0.00	41.78	2473.33		0.00
10		1.00	1.00	0.00	14.64	2487.98		0.00
11		1.00	1.00	0.00	.90	2488.88		0.00
44	D	1.00	1.00	0.00	0.00	2488.88		*9587.58
12		1.00	1.00	0.00	196.78	2685.66		0.00
13		1.00	1.00	0.00	2.17	2687.83		0.00
14		1.00	1.00	0.00	29.81	2717.64		0.00
15		1.00	1.00	0.00	3.82	2721.47		0.00
16		1.00	1.00	0.00	105.10	2826.57		0.00
17		1.00	1.00	0.00	1.22	2827.78		0.00
18		1.00	1.00	0.00	97.79	2925.58		0.00
19		1.00	1.00	0.00	5.26	2930.84		0.00
20		1.00	1.00	0.00	33.78	2964.62		0.00

45	D	1.00	1.00	0.00	0.00	2964.62	*0300.10
46	D	1.00	1.00	0.00	0.00	2964.62	.00
21		1.00	1.00	0.00	3.00	2967.61	0.00
22		1.00	1.00	0.00	20.74	2988.36	0.00
23		1.00	1.00	0.00	2.25	2990.61	0.00
24		1.00	1.00	0.00	18.29	3008.90	0.00
25		1.00	1.00	0.00	8.11	3017.01	0.00
26		1.00	1.00	0.00	2.34	3019.35	0.00
27		1.00	1.00	0.00	8.32	3027.68	0.00
28		1.00	1.00	0.00	11.27	3038.94	0.00
29		1.00	1.00	0.00	4.78	3043.73	0.00
30		1.00	1.00	0.00	3.18	3046.90	0.00
31		1.00	1.00	0.00	3.64	3050.54	0.00
32		1.00	1.00	0.00	25.97	3076.51	0.00
33		1.00	1.00	0.00	3.92	3080.43	0.00
34		1.00	1.00	0.00	3.80	3084.23	0.00
35		1.00	1.00	0.00	3.02	3087.25	0.00
36		1.00	1.00	0.00	9.49	3096.74	0.00
37		1.00	1.00	0.00	4.69	3101.43	0.00
38		1.00	1.00	0.00	3.33	3104.76	0.00
39		1.00	1.00	0.00	7.40	3112.15	0.00
40		1.00	1.00	0.00	22.12	3134.27	0.00
41		1.00	1.00	0.00	2.31	3136.58	0.00
42		1.00	1.00	0.00	.85	3137.43	0.00
43		1.00	1.00	0.00	82.64	3220.06	0.00
47	D	1.00	1.00	0.00	0.00	3220.06	.00
48	D	1.00	1.00	0.00	0.00	3220.06	.00
49	D	1.00	1.00	0.00	0.00	3220.06	*0000.00
50		1.00	1.00	0.00	198.74	3418.81	0.00

SUMMARY OUTPUT OF ITERATION 1 RUN 1 TRIAL 1
UNDER RUN TOTAL TIME USED 3418.81

OPR NO	THRES HOLD	SPEED	AVAIL	TIMES USED	DIFF	WAIT	PEAK TASK	STRESS VALUE	FINAL STRESS	LAST COMES	CYCLIC WAIT
1	2.30	1.00	10000.00	3418.81	-6581.2	0.0	1	1.00	1.00	0.00	0.00
2	2.30	1.00	10000.00	.75	-9999.2	0.0	1	1.00	1.00	0.00	0.00

DETAIL OUTPUT OF ITERATION 2 RUN 1 TASK 1

OPERATOR 1

TASK NO	TASK TYPE	NON ESS	STRESS IND	STRESS TOT	TIMES WAIT	TIMES TASK	TIMES CUM	SFI	COMES
1			1.00	1.00	0.00	3.85	3.85		0.00
2			1.00	1.00	0.00	9.02	12.87		0.00
3			1.00	1.00	0.00	2.21	15.08		0.00
4			1.00	1.00	0.00	1.83	16.91		0.00
5			1.00	1.00	0.00	1.86	18.77		0.00
6			1.00	1.00	0.00	2.72	21.49		0.00
7			1.00	1.00	0.00	1.79	23.29		0.00
8			1.00	1.00	0.00	9.31	32.59		0.00
9			1.00	1.00	0.00	116.29	148.89		0.00
10			1.00	1.00	0.00	12.93	161.81		0.00
11			1.00	1.00	0.00	.81	162.62		0.00
44	D		1.00	1.00	0.00	0.00	162.62		*9587.58
12			1.00	1.00	0.00	172.71	335.33		0.00
13			1.00	1.00	0.00	2.20	337.53		0.00
14			1.00	1.00	0.00	37.02	374.55		0.00
15			1.00	1.00	0.00	3.05	377.61		0.00
16			1.00	1.00	0.00	62.19	439.80	F	0.00
16			1.00	1.00	0.00	45.60	485.39		0.00
17			1.00	1.00	0.00	1.14	486.53		0.00
18			1.00	1.00	0.00	129.81	616.34		0.00
19			1.00	1.00	0.00	5.41	621.75		0.00
20			1.00	1.00	0.00	50.34	672.09		0.00
45	D		1.00	1.00	0.00	0.00	672.09		*0300.10
46	D		1.00	1.00	0.00	0.00	672.09		.00
21			1.00	1.00	0.00	2.34	674.43		0.00
22			1.00	1.00	0.00	26.81	701.24		0.00
23			1.00	1.00	0.00	1.34	702.58		0.00
24			1.00	1.00	0.00	15.58	718.16		0.00
25			1.00	1.00	0.00	8.93	727.08		0.00
26			1.00	1.00	0.00	2.20	729.29		0.00
27			1.00	1.00	0.00	9.94	739.22		0.00
28			1.00	1.00	0.00	12.88	752.10		0.00
29			1.00	1.00	0.00	2.93	755.04		0.00
30			1.00	1.00	0.00	2.13	757.17		0.00
31			1.00	1.00	0.00	2.61	759.78		0.00
32			1.00	1.00	0.00	22.69	782.47		0.00
33			1.00	1.00	0.00	4.05	786.52		0.00
34			1.00	1.00	0.00	2.74	789.26		0.00
35			1.00	1.00	0.00	3.01	792.26		0.00
36			1.00	1.00	0.00	15.74	808.01		0.00
37			1.00	1.00	0.00	4.13	812.14		0.00
38			1.00	1.00	0.00	3.63	815.77		0.00
39			1.00	1.00	0.00	10.63	826.40		0.00
40			1.00	1.00	0.00	15.84	842.24		0.00
41			1.00	1.00	0.00	2.18	844.43		0.00
42			1.00	1.00	0.00	1.41	845.84		0.00
43			1.00	1.00	0.00	91.02	936.86		0.00
47	D		1.00	1.00	0.00	0.00	936.86		.00

OPERATOR 2

TASK NO	TASK TYPE	NON ESS	STRESS IND	STRESS TOT	TIMES WAIT	TIMES TASK	TIMES CUM	SFI	COMES
1			1.00	1.00	0.00	.75	.75		0.00

48	D	1.00	1.00	0.00	0.00	935.85	-.00
49	D	1.00	1.00	0.00	0.00	936.86	*0000.00
50		1.00	1.00	0.00	247.22	1184.08	0.00

SUMMARY OUTPUT OF ITERATION 2 RUN 1 TRIAL 1
UNDER RUN TOTAL TIME USED 1184.08

OPR NO	THRES HOLD	SPEED	AVAIL	T I M E S USED	DIFF	WAIT	PEAK STRESS TASK	VALUE	FINAL STRESS	LAST COMES	CYCLIC WAIT
1	2.30	1.00	10000.00	1184.08	-8815.9	0.0	1	1.00	1.00	0.00	0.00
2	2.30	1.00	10000.00	.75	-9999.2	0.0	1	1.00	1.00	0.00	0.00

SUMMARY OUTPUT OF ITERATION 3 RUN 1 TRIAL 1
UNDER RUN TOTAL TIME USED 1117.84

OPR NO	THRES HOLD	SPEED	AVAIL	T I M E S USED	DIFF	WAIT	PEAK STRESS TASK	VALUE	FINAL STRESS	LAST COMES	CYCLIC WAIT
1	2.30	1.00	10000.00	1117.84	-8882.2	0.0	1	1.00	1.00	0.00	0.00
2	2.30	1.00	10000.00	.75	-9999.2	0.0	1	1.00	1.00	0.00	0.00

SUMMARY OUTPUT OF ITERATION 4 RUN 1 TRIAL 1
UNDER RUN TOTAL TIME USED 1919.82

OPR NO	THRES HOLD	SPEED	AVAIL	T I M E S USED	DIFF	WAIT	PEAK STRESS TASK	VALUE	FINAL STRESS	LAST COMES	CYCLIC WAIT
1	2.30	1.00	10000.00	1919.82	-8080.2	0.0	1	1.00	1.00	0.00	0.00
2	2.30	1.00	10000.00	.75	-9999.2	0.0	1	1.00	1.00	0.00	0.00

SUMMARY OUTPUT OF ITERATION 5 RUN 1 TRIAL 1
UNDER RUN TOTAL TIME USED 1315.84

OPR NO	THRES HOLD	SPEED	AVAIL	T I M E S USED	DIFF	WAIT	PEAK STRESS TASK	VALUE	FINAL STRESS	LAST COMES	CYCLIC WAIT
1	2.30	1.00	10000.00	1315.84	-8684.2	0.0	1	1.00	1.00	0.00	0.00
2	2.30	1.00	10000.00	.75	-9999.2	0.0	1	1.00	1.00	0.00	0.00

SUMMARY OUTPUT OF RUN 1
NUMBER OF ITERATIONS 5
NUMBER OF SUCCESSES 5
PER CENT SUCCESSES 100.0 FOR TIME DURATION 10000.00

OPR NO	THRES HOLD	SPEED	AVERAGE TIMES AVAIL	USED	DIFF	WAIT	PEAK STRESS	FINAL STRESS	CYCLIC WAIT
1	2.30	1.00	10000.00	1791.28	-8208.72	0.00	1.00	1.00	0.00
2	2.30	1.00	10000.00	.75	-9999.25	0.00	1.00	1.06	0.00

FREQUENCY DATA

TASK NO	LAST TASK COMPLETED OP 1	OP 2	TASK FAILED OP 1	OP 2	TASK IGNORED OP 1 NE	OP 2 NE
1	0	5	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0
9	0	0	10	0	0	0
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	0	0	0
16	0	0	1	0	0	0
17	0	0	0	0	0	0
18	0	0	0	0	0	0
19	0	0	0	0	0	0
20	0	0	0	0	0	0
21	0	0	0	0	0	0
22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0
25	0	0	0	0	0	0
26	0	0	1	0	0	0
27	0	0	0	0	0	0
28	0	0	0	0	0	0
29	0	0	0	0	0	0
30	0	0	0	0	0	0
31	0	0	0	0	0	0
32	0	0	0	0	0	0
33	0	0	0	0	0	0
34	0	0	0	0	0	0
35	0	0	0	0	0	0
36	0	0	0	0	0	0
37	0	0	0	0	0	0
38	0	0	0	0	0	0
39	0	0	0	0	0	0
40	0	0	0	0	0	0
41	0	0	0	0	0	0

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

42	0	0	0	0	0	0
43	0	0	0	0	0	0
44	0	0	0	0	0	0
45	0	0	0	0	0	0
46	0	0	0	0	0	0
47	0	0	0	0	0	0
48	0	0	0	0	0	0
49	0	0	0	0	0	0
50	5	0	0	0	0	0
		TOTAL	20	0	0	0
		AVERAGE	4.0	0.0	0.0	0.0

SUMMARY OUTPUT OF RUN 1

TASK	FAILURE TIMES		PEAK STRESS		AVG TIME CMPLTD		AVG START TOT STRESS		AVG COM-SIVE	
NO	OP 1	OP 2	OP 1	OP 2	OP 1	OP 2	OP 1	OP 2	OP 1	OP 2
1	0.00	0.00	5	5	504.24	.75	1.00	1.00	0.00	0.00
2	0.00	0.00	0	0	512.82	0.00	1.00	0.00	0.00	0.00
3	0.00	0.00	0	0	515.90	0.00	1.00	0.00	0.00	0.00
4	0.00	0.00	0	0	519.81	0.00	1.00	0.00	0.00	0.00
5	0.00	0.00	0	0	521.86	0.00	1.00	0.00	0.00	0.00
6	0.00	0.00	0	0	524.66	0.00	1.00	0.00	0.00	0.00
7	0.00	0.00	0	0	526.61	0.00	1.00	0.00	0.00	0.00
8	0.00	0.00	0	0	535.20	0.00	1.00	0.00	0.00	0.00
9	2450.29	0.00	0	0	952.54	0.00	1.00	0.00	0.00	0.00
10	0.00	0.00	0	0	966.82	0.00	1.00	0.00	0.00	0.00
11	0.00	0.00	0	0	968.86	0.00	1.00	0.00	0.00	0.00
12	0.00	0.00	0	0	905.19	0.00	1.00	0.00	0.00	0.00
13	0.00	0.00	0	0	907.20	0.00	1.00	0.00	0.00	0.00
14	0.00	0.00	0	0	937.12	0.00	1.00	0.00	0.00	0.00
15	0.00	0.00	0	0	939.96	0.00	1.00	0.00	0.00	0.00
16	62.19	0.00	0	0	1037.91	0.00	1.00	0.00	0.00	0.00
17	0.00	0.00	0	0	1038.88	0.00	1.00	0.00	0.00	0.00
18	0.00	0.00	0	0	1114.97	0.00	1.00	0.00	0.00	0.00
19	0.00	0.00	0	0	1121.39	0.00	1.00	0.00	0.00	0.00
20	0.00	0.00	0	0	1165.06	0.00	1.00	0.00	0.00	0.00
21	0.00	0.00	0	0	1167.27	0.00	1.00	0.00	0.00	0.00
22	0.00	0.00	0	0	1196.18	0.00	1.00	0.00	0.00	0.00
23	0.00	0.00	0	0	1198.22	0.00	1.00	0.00	0.00	0.00
24	0.00	0.00	0	0	1214.65	0.00	1.00	0.00	0.00	0.00
25	0.00	0.00	0	0	1225.40	0.00	1.00	0.00	0.00	0.00
26	1.33	0.00	0	0	1228.41	0.00	1.00	0.00	0.00	0.00
27	0.00	0.00	0	0	1236.94	0.00	1.00	0.00	0.00	0.00
28	0.00	0.00	0	0	1251.03	0.00	1.00	0.00	0.00	0.00
29	0.00	0.00	0	0	1254.31	0.00	1.00	0.00	0.00	0.00
30	0.00	0.00	0	0	1257.52	0.00	1.00	0.00	0.00	0.00
31	0.00	0.00	0	0	1260.35	0.00	1.00	0.00	0.00	0.00
32	0.00	0.00	0	0	1281.01	0.00	1.00	0.00	0.00	0.00
33	0.00	0.00	0	0	1284.92	0.00	1.00	0.00	0.00	0.00
34	0.00	0.00	0	0	1287.61	0.00	1.00	0.00	0.00	0.00
35	0.00	0.00	0	0	1298.62	0.00	1.00	0.00	0.00	0.00
36	0.00	0.00	0	0	1306.21	0.00	1.00	0.00	0.00	0.00
37	0.00	0.00	0	0	1310.22	0.00	1.00	0.00	0.00	0.00
38	0.00	0.00	0	0	1313.52	0.00	1.00	0.00	0.00	0.00
39	0.00	0.00	0	0	1322.42	0.00	1.00	0.00	0.00	0.00
40	0.00	0.00	0	0	1336.51	0.00	1.00	0.00	0.00	0.00
41	0.00	0.00	0	0	1339.42	0.00	1.00	0.00	0.00	0.00
42	0.00	0.00	0	0	1340.42	0.00	1.00	0.00	0.00	0.00
43	0.00	0.00	0	0	1447.51	0.00	1.00	0.00	0.00	0.00
44	0.00	0.00	0	0	762.86	0.00	1.00	0.00	0.00	0.00
45	0.00	0.00	0	0	1165.06	0.00	1.00	0.00	0.00	0.00
46	0.00	0.00	0	0	1165.86	0.00	1.00	0.00	0.00	0.00
47	0.00	0.00	0	0	1567.91	0.00	1.00	0.00	0.00	0.00
48	0.00	0.00	0	0	1567.91	0.00	1.00	0.00	0.00	0.00
49	0.00	0.00	0	0	1567.91	0.00	1.00	0.00	0.00	0.00

```
50     0.00     0.00     0     0    1791.24    0.00    1.00    0.00    0.00    0.00
     -------  -------
     2513.81     0.00  TOTAL

      502.76     0.00  AVERAGE

END-OF-FILE ENCOUNTERED. FILENAME:      INPUT
ERROR NUMBER   0005 DETECTED BY INPUTC   AT ADDRESS 000040
CALLED FROM INPUT    AT  LINE 0051
CALLED FROM PAR4     AT  LINE 0125

ERROR SUMMARY
   ERROR      TIMES
     00        0001
```

B-65

```
DMPX.

P    063367  A0  000101  B0  000000
RA   157700  A1  000001  B1  000000   C(A1)=  0102  2400  0000  0000  0000   C(B1)=  0000  0000  0000  0000  0000
FL   100000  A2  004116  B2  044575   C(A2)=  0231  5511  1620  2524  0300   C(B2)=  1725  2420  2524  0074  0035
EM   070000  A3  057643  B3  000665   C(A3)=  1116  2025  2403  0005  7703   C(B3)=  5255  0000  0000  0000  0000
RE   000000  A4  063411  B4  000315   C(A4)=  0400  0577  2400  0000  0000   C(B4)=  5533  3650  3537  5042  3455
FE   000000  A5  044575  B5  000001   C(A5)=  1725  2420  2524  0074  0035   C(B5)=  0103  2400  0000  0000  0000
MA   000000  A6  000001  B6  777776   C(A6)=  0102  2400  0000  0000  0000   C(B6)=
             A7  000001  B7  000001   C(A7)=  0102  2400  0000  0000  0000   C(B7)=  0103  2400  0000  0000  0000
X0   0000  0000  0000  0000  0034
X1   0000  0000  0000  0000  0000
X2   0000  0000  0000  0006  4114
X3   0000  0000  0000  0006  4111
X4   1523  0700  0000  0000  0000
X5   1523  0700  0000  0000  0000
X6   0102  2400  0000  0000  0004
X7   1523  0700  0000  0006  4111

   00000   00000 00000 00000 00000        01027 40000 00000 00000         11162 02524 00000 42553         17252 42025 24000 44575
   00004   24012 00540 00000 42553        24012 00541 00000 44575         00000 00000 00000 00000         06241 62215 01200 00204
   00010   06241 61720 24000 00221        00000 00000 00000 00000         00000 00000 00000 57673         00000 00000 00000 57573
   00014   00000 00000 00000 00000
   00020  *00000 00000 00000 05122        00000 00000 00000 00000
   00024  *00000 00000 00000 00015        00000 00000 00000 00000   00032*00000 00000 00000 57544         00000 00000 00000 00000
   00037  *00000 00000 00000 00047
   00040   00000 00000 00000 00000  00043*00000 00000 00000 57566
   00044   00000 00000 00000 00000  00046*01555 55555 55555 55536         00000 00000 00000 00011
   00050   00000 00000 00000 00000  00052*00000 00000 00000 00001         00000 00000 00000 00000   00056*20020 00000 00000 00000
   00057   00000 00000 00000 00000  00061*00000 00000 00000 57544         00000 00000 00000 00000
   00064  *14071 70000 00000 00000        00000 00000 00000 64313         00070 54110 00000 42553         00000 00000 20000 73774
   00070   00000 00000 00000 00000
   00100  *17326 77643 21762 04206

   63267   24015 50317 22205 75534
   63270   44423 35555 55555 55555        04000 46626 00000 00000         74600 51200 00064 43052         61300 00002 51600 00076
   63274   63220 46000 46000 46000        03010 63302 11701 46000         04200 63301 56130 46000         03030 63300 11703 46000
   63300   61227 77776 46000 46000        53410 03140 63302 53710         10611 56630 03010 63305         61330 00001 50110 00001
   63304   04000 63275 46000 46000        56500 20560 03250 63271         51500 00064 43052 11605         51600 63324 61100 00001
   63310   51200 63271 54111 21236        72320 00077 10611 21306         72430 01000 20330 20414         12734 51600 63321 46000
   63314   71200 00020 20260 12727        54761 51500 63320 46000         01000 63345 46000 46000         04000 63271 46000 46000
   63320   23203 12000 00000 63322        00000 00000 00000 00000   63323*22031 42000 00000 63322
   63324   00000 00000 00000 00000        20221 62423 20310 00001         15230 70000 00000 63327         20221 62423 20310 00000
   63330   00000 00000 00000 00000        51100 63322 01010 63330         43600 61100 00001 54610         51500 63323 01000 63345
   63334   51100 63325 51200 63324        51500 63326 10611 22702         51600 00064 56711 43600         54671 01000 63345 46000
   63340   71501 40426 20552 46000        01000 63345 46000 46000         00000 00000 46000 46000         56510 03150 63343 54650
   63344   54550 20523 03350 63344        00000 00000 00000 00000         10655 04000 63343 46000         55550 43033 55304 24730
   63350   61700 00001 51600 56514        51100 63347 46000 46000         21136 52217 77776 53320         54437 20406 12547 77775
   63354   03150 63356 64140 46000        02100 00000 46000 46000         43030 51400 63370 20344         15530 12745 11603 54740
   63360   54677 74270 71101 52307        20152 12612 46000 46000         56370 03170 63362 56670         77107 01000 63512 46000
   63364   01000 63330 46000 46000        71600 51604 20652 46000         56170 03110 63366 56670         00000 00000 46000 46000
   63370   05160 45500 00000 00000        00000 00000 00000 00000         41000 00000 00000 00000         61700 00001 71200 63377
   63374   71101 52307 20152 12712        56170 03110 63375 56770         04000 63363 46000 46000         05301 12400 00000 00000
   63400   00000 00000 00000 00000        61700 00001 51100 63407         20736 43036 15370 11607         36712 54710 54677 74270
   63404   71501 52307 20552 46000        56470 03140 63405 12625         56670 04000 63363 46000         23241 72055 00000 00000
```

63410	00000	00000	00000	00000
63414	12621	21436	54630	46000
63420	76700	54777	71401	52707
63424	56670	71600	10224	20452
63430	03570	00000	00000	00000
63434	51410	64126	03320	63437
63440	15440	21044	15220	10122
63444	50220	00002	03320	63447
63450	11604	15120	12441	46000
63454	00000	00000	00000	00000
63460	55552	33033	55374	03707
63464	21136	52217	77776	53320

04000	57724	00000	00000
52247	77776	53320	21322
71300	64111	20452	12743
04000	63366	46000	46000
61700	00601	50410	00001
76370	20323	15443	46000
20264	03120	63443	54321
43014	20054	15440	20240
54227	03320	63453	10622
50210	00001	51400	63454
74700	51700	63510	10611
73720	51500	63471	53430

61700	00001	51300	64062
51100	64115	10711	54767
56170	03110	63422	56770
71600	10224	20652	46000
53510	63150	53240	46000
03020	63437	12443	46000
03330	63444	03030	63444
03020	63447	11202	17424
51600	64057	46000	46000
10644	51600	63512	53110
51100	63460	10733	46000
51700	63505	74140	36614

51300	64114	51400	63411
54217	12723	54777	74260
56170	03110	63423	36642
04000	63366	46000	46000
61200	00164	07210	63430
54227	03320	63444	43020
20354	12424	12434	46000
54227	03320	63451	43052
10744	54740	04000	63430
04000	63513	46000	46000
51600	63503	51700	63504
10755	51600	63502	54740

APPENDIX B2 - PROGRAM LISTING

This appendix contains the program listing for the 4-20 man digital simulation model.

```
65686 01  09-27-76   14.083

CXMAIN          XMAIN
      COMMON/PRSNEL/WT,SIGWT,PPFQ,PPMQ,PPUQ,SPFQ,SPMQ,SPUQ,
     1MPI,PID,ZPC,PTT(10,10),MEN(10,4),NDS,IDS(6,20)
      COMMON/IPARAM/APST,WORK1,WORK2,SLEEP,CN,MAXSL,TFAT,ACP,
     1CALRY,PWHRT,K7,K1,BE,AASP,USHLIM,KON(10),KONT(10,10),KON1(10),
     2 KONT1(10,10),SESTA(10),RELI(4),N,IET,IND(7),NDMAX,IDFR(38,12)
      COMMON/EQREVNT/ IDF(30),RELH(30),DTR(570),TUI(30),IRE(30)
      COMMON/EEMER/ART(10),ASDE(10),DTE(10),IESSE(10) ,NREQE(10,10),
     1 LODME(10),IRCE(10,10),IRCE1(10,10),TSE(10),TSE1(10),IHE(10),
     1 IECE(10,10),DTBE(10),NDBE(10)
      COMMON/ETYPE/ADUR,ASD,IESS,NREQ(10),LODM,KE,INT,IRC(10),IRC1(10),
     1 IH,IEC(10),NIOR,IOR(6),ICLASS
      COMMON/SEVENT/IETYP(570),TL(570),ST(570),EDCV(3,570),IPE(570),
     1 TS(570),TS1(570),NX(3,570),RTU(570),IFOI(570),IEFN(570),NIF(570),
     2  IEDC(3,570),PRB(3,570),NOSE,NEQRE,NEME,DI(9)
      COMMON/QCOM/PCOM(20),SCOM(20),IPS(20),ISS(20),TPCOM(20),TSCOM(20)
       COMMON/OPP1/ IAA(4),PC(20),PACE(20),ASP(20),HSLS(20),PI(20)
     1,PI2(20),ICE(20)
       COMMON/OPP2/ TW(20),TWP(20),TWS(20),DS(20),APN(20),PCC(20),
     1              CASP(20),IDC(20),         NSUC1,NSUC2,NFALE,NIGNR,
     2 KONC(10),KONC1(10), SI,CML,ND,ITER,NDAYS,MPCC(20),FAT(20)
     3 ,STRM(20),CAL(20),PWR(20),CCAL(20),NU(20),PERF(20),NPRFM(4)
     4 ,APA,SFDIFF,CLSDTA(10,40)
       COMMON/OPP3/IC,FLIC,NREPT,HRSE,HRSR,HRSS,PEFF,
     1 MAXST,MAXSTE,USHT,NR,NTE,NE,TFH,CMLMX,ICML,SIDCMX,IDCMX,ICSS
      COMMON/OPP4/EPL(30),CDT(30),CART(30),CUT(30),
     1      EPEFF,EMTBF,EMTTR,SRL,SPL,SGEM,RSSUC2,SCDTID,REPTM,
     1        ACART(10),ACDT(10),ACUT(10), AEPL(10),DEPEFF(10)
C    1 AEPL,EPEFF,EMTBF,EMTTR,SRL,SPL,SGEM
      INTEGER HEADR
      INTEGER TS,TS1,RTU,TSE,TSE1,TSR,TSR1
      INTEGER PI2,PTR(240),IOIF(10)
       REAL KONC,NOSUC(20),NOFAIL(20),IDC,KONE(20),MPCC     ,MAXST,NU
      REAL MPI,MAXSL,K7,K1,IEC,LODM,IH,IRC,KON,KON1,KONT,KONT1
       REAL IECE,IHE,IRCE,LODME,IST
      DIMENSION NPTR(580),ADURIO(55)
     1 ,KONE1(20),IKONC(20),IKONE(20)
       DIMENSION PSCOM(40),IPSS(40),PCDUM(6),TPSCOM(40)
       EQUIVALENCE (PCDUM,PPFQ),(PSCOM,PCOM),(IPSS,IPS),(TPSCOM,TPCOM)
      EQUIVALENCE (ADUR,ADURIO)
      DIMENSION NS(20),IDE(10),
     1                   Z(20),ZC(570),IEVENT(570),NREQT(10),MAVAIL(20),
     2            TAVAIL(20),MA(20,10),ITYPE(20),MAT(20),WH(20),ACAL(20),
     3 RT(570),TITLE(9)
       DIMENSION MCHSN(20),INVS(570)
      DIMENSION HEADR(12),IDFFF(30)
      DATA HEADR(1)/72H APPLIED PSYCHOLOGICAL SERVICES       WAYNE, PENNA
     1.       ARTHUR I, SIEGEL/
       DATA TITLE/6HSCHEDU,6HLED EV,6HENT   ,6HREPAIR,6H EVENT,
     16H      ,6HEMERGE,6HNCY EV,6HENT   /
       DATA YU,ESSS,PEA/6H     U,6H     S,6H     P/
```

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```
      DATA STAR,BLANK/6H      *,6H      /                             MAIN0500
      DATA REPAIR/6HREPAIR/
      FUNC(A,B, D) = (A + (A*B)/4.) *  D                              MAIN0510
      CALL RANSIZ(12,55)                                              MAIN0520
      READ(5,9050) NKASES                                             MAIN0530
      KASE = 0                                                        MAIN0540
   10 KASE = KASE+1                                                   MAIN0550
      IF(KASE .GT. NKASES)  CALL EXIT                                 MAIN0560
      READ(5,9045) HEADR                                              MAIN0570
 9045 FORMAT(12A6)                                                    MAIN0580
      DO 20 I=1,12
      IDFR(1,I)=HEADR(I)
   20 CONTINUE
      CALL SPGHDR(HEADR)                                              MAIN0590
      LMAX=10                                                         MAIN0600
      LMAX1=10                                                        MAIN0610
      NTMAX=10                                                        MAIN0620
      ITER=0                                                          MAIN0630
      NKOUNT = 0                                                      MAIN0640
      READ(5,9050) ITAP,NDMAX                                         MAIN0650
      CALL XXIN                                                       MAIN0660
   50 ITER=ITER+1                                                     MAIN0670
      ITAP = ITAP+1                                                   MAIN0680
      NDAYS = 0                                                       MAIN0690
 9050 FORMAT (2I3)                                                    MAIN0700
      CALL INPUT(ITAP,KASE)                                           MAIN0710
      KMAX=NEME                                                       MAIN0720
      IOMAX=NEORE                                                     MAIN0730
      IEMAX=NOSE+NEORE+NEME                                           MAIN0740
C***COUNT THE CREW FOR EACH ECHELON AND ASSIGN                         MAIN0750
C***EACH MAN A CREW ECHELON                                            MAIN0760
      IC = 0                                                          MAIN0770
      DO 110 I = 1,4                                                  MAIN0780
      IAA(I) = 0                                                      MAIN0790
      DO 100 J = 1,NTMAX                                              MAIN0800
  100 IAA(I) = IAA(I)+MEN(J,I)                                        MAIN0810
  110 IC = IAA(I)+IC                                                  MAIN0820
      FLIC = IC                                                       MAIN0830
      II = 1                                                          MAIN0840
      JJ = 0                                                          MAIN0850
      DO 120 I = 1,4                                                  MAIN0860
      JJ = IAA(I)+JJ                                                  MAIN0870
      IF (JJ.LT.II) GO TO 120                                         MAIN0880
      DO 115 J = II,JJ                                                MAIN0890
  115 ICE(J) = I                                                      MAIN0900
      II = JJ+1                                                       MAIN0910
  120 CONTINUE                                                        MAIN0920
C***ASSIGN PRIMARY SPECIALTIES                                         MAIN0930
      M = 1                                                           MAIN0940
      DO 160 J = 1,4                                                  MAIN0950
      DO 160 I = 1,NTMAX                                              MAIN0960
```

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```
      II = MEN(I,J)
      IF (II.EQ.0) GO TO 160
      DO 155 K = 1,II
      IRS(M) = I
  155 M = M+1
  160 CONTINUE
C***ASSIGN SECONDARY SPECIALTIES
      DO 220 I = 1,IC
      II = IPS(I)
      TEM1 = UNIFM1(0,0)
      TEM1 = TEM1*PTT(NTMAX,II)
      DO 210 J = 1,NTMAX
      IF (PTT(J,II).LT.TEM1) GO TO 210
      ISS(I) = J
      GO TO 220
  210 CONTINUE
  220 CONTINUE
C***PC,CAL,PWR,PACE,ASP,HSLS,FAT,STRM  FOR
C***EACH MAN
      DO 300 I = 1,IC
      TEM1 = DNORM1(0.0)
       PC(I)=(WT+TEM1*SIGHT)/WT
      CAL(I) = PC(I)*CALRY
      PWR(I) = PC(I)*PWRRT
      PACE(I) = ACP + DNORM1(0.0) * 0.11
      ASP(I) = AMIN1(AASP+AASP*DNORM1(0,0)/10,0,1,0)
      HSLS(I) = SLEEP+DNORM1(0,0)*SLEEP*0,25
       FAT(I)=FBUILD(HSLS(I))
  300 STRM(I) = APST+DNORM1(0.0)*APST/6.0
C***CALCULATE PRIMARY AND SECONDARY COMPETANCE
C***FOR EACH MAN AND CCI=INITIAL CREW COMPETANCE
      CALL PSCAP(IAA,PCDUM, PSCOM)
      CCI = 0.0
      DO 360 I = 1,IC
  360 CCI = CCI+ PCOM(I)
      CCI = CCI/FLIC
C***CALCULATE PHYSICAL INCAPACITIES
  365 DO 370 I = 1,IC
       PI(I)=1.0
  370  PI2(I)=0
      NPI = IPUYSN(FLIC/MPI)
      IF (NPI.EQ.0) GO TO 390
      DO 380 I = 1,NPI
      II = UNIFM1(0,0)*FLIC
      PI(II) = 0.2*UNIFM1(0.0)+0.75
  380 PI2(II) = IPUYSN(PID)
  390 CALL OUTP1
C***FIRST DAY OF ITERATION---INITIALIZATIONS
  550 ND = 1
      DO 560 I = 1,KMAX
  560 IDE(I) = 0
```

```
      DO 570 I = 1,IQMAX
  570 IDF(I) = 0
      DO 580 I = 1,LMAX
  580 KONC(I) = KON(I)
      DO 585 I =1,LMAX1
  585 KONC1 (I) = KON1 (I)
      DO 590 I = 1,IC
      NS(I) = 0
      ACAL(I) = HSLS(I)*CAL(I)/24.0
      CASP(I) = ASP(I)
       PERF(I)=ASP(I)
      NOSUC(I) = 0.0
  590 NOFAIL(I) = 0.0
C
C     DETERMINE DAY OF OCCURRENCES OF NEXT FAILURES AND EMERGENCIES FOR
C     FAILURE AND EQUIPMENT
C
      WRITE(6,8001) IQMAX
 8001 FORMAT(' *****IQMAX=',I7)
      WRITE(6,8002) (RELM(I),I=1,IQMAX)
 8002 FORMAT(' **** RELM=',(8F10.3))
      DO 605 I = 1,IQMAX
      II =               RELM (I) * ALOG(UNIFM1(0,0)) - 0.5
      IF(II.EQ.0)II=-1
  605 IDF(I) = IDF(I)-II
      WRITE(6,8004) (IDF(I),I=1,IQMAX)
 8004 FORMAT(' ***** IDF=',(8I10))
      WRITE(6,8005) KMAX
 8005 FORMAT(' **** KMAX=',I7)
      WRITE(6,8006)(NDRE(I),I=1,KMAX)
 8006 FORMAT(' **** NDRE=',(8I8))
      DO 610 I = 1,KMAX
      II =               NDRE(I) *ALOG(UNIFM1(0,0)) - 0.5
      IF(II.EQ.0)II=- 1
  610 IDE(I) = IDE (I) - II
      WRITE(6,8007) (IDE(I),I=1,KMAX)
 8007 FORMAT(' **** IDE=',(8I8))
      IF (IND(3).EQ.0) GO TO 650
C***BEGIN SIMULATION FOR EACH DAY---INITIALIZATIONS
  650  RIGNR=0
C      RSSUC2=0.
C      SEDTIQ=0.
C      REPTM=0.
       NSUC1=0
       NSUC2=0
       NFALE=0
       NREPT=0
       DO 655 I=1,4
  655  NPRFM(I)=0
      DO 658  J=1,10
       DO 658 I=1,40
```

```
  650 ELSDTA(J,I)= 0.0                                         MAIN2050
      WSHT = 0.0                                               MAIN2060
       WRSE=0.0                                                MAIN2070
       WRSR=0.0                                                MAIN2080
       WRSS=0.0                                                MAIN2090
       MAXSTE=0.0                                              MAIN2100
       MAXSTE=0                                                MAIN2110
      DO 660 I = 1,IEMAX                                       MAIN2120
  660 ZE(I) = 0.0                                              MAIN2130
      DO 670 I = 1,IC                                          MAIN2140
      TW(I) = 0.0                                              MAIN2150
       TWP(I)=0.0                                              MAIN2160
       TWS(I)=0.0                                              MAIN2170
       SPCC(I)=0.0                                             MAIN2180
      TDC(I) = 0.0                                             MAIN2190
      DS(I) = 0.0                                              MAIN2200
       RV(I)=0.0                                               MAIN2210
  670 X(I) = 0.0                                               MAIN2220
      CRL = 0.0                                                MAIN2230
      CMLMX=-1.E10                                             MAIN2240
       ICML=0                                                  MAIN2250
       SIDCMX=CMLMX                                            MAIN2260
       IDCMX=0                                                 MAIN2270
      TSN = 0.0                                                MAIN2280
       SPDIFF=0.0                                              MAIN2290
       SEF=0.0                                                 MAIN2300
       ISIE=0                                                  MAIN2310
       APA=0.0                                                 MAIN2320
      DO 675 I=1,IQMAX                                         MAIN2330
      CUT(I) = 0.0                                             MAIN2340
      CBT (I) = 0.0                                            MAIN2350
      CART(I) = 0.0                                            MAIN2360
      SPL(I)=0.0                                               MAIN2370
  675 CONTINUE                                                 MAIN2380
C                                                              MAIN2390
C     CALCULATE SEA STATE                                      MAIN2400
C                                                              MAIN2410
      ICSS =0                                                  MAIN2420
      ATEN = UNIFM1 (0.0)                                      MAIN2430
      DO 680 I=1,9                                             MAIN2440
  705 FORMAT(1H0,2I5,2F7.4)                                    MAIN2450
      IF (ATEN .GT. SESTA (I) ) GO TO 680                      MAIN2460
      ICSS = I - 1                                             MAIN2470
      GO TO 685                                                MAIN2480
  680 CONTINUE                                                 MAIN2490
  685 PSESIC = 0.0555 * ICSS                                   MAIN2500
      DO 690 I=1,IC                                            MAIN2510
      TPCOM (I) = PCOM (I)                                     MAIN2520
      TSCOM (I) = SCOM (I)                                     MAIN2530
      IF (UNIFM1(0.0)  .GE. PSESIC) GO TO  690                 MAIN2540
      TPCOM (I) = TPCOM (I) * (1- ICSS* 0.0555)                MAIN2550
```

```
      TSCOM (I) = TSCOM (I) * (1- ICSS* 0.0555)                         MAIN2560
  690 CONTINUE                                                          MAIN2570
      IXDF=MIN0(IQMAX,KMAX)
      I=1
      WRITE(6,9610) (I,IDF(1),I,IDE(1),ICSS,PSESIC)
      IF(IXDF.LT.2) GO TO 682
      DO 681 I=2,IXDF
      WRITE(6,9620) I,IDF(I),I,IDE(I)
  681 CONTINUE
  682 CONTINUE
 9610 FORMAT(1H1,'PRINT OPTION THREE - OCCURANCES OF FAILURES AND EMERGE
     1NCIES, SEA STATE AND SICKNESS'//,'EQUIPMENT  DAY OF FIRST  EMERGEN
     2CY  DAY OF FIRST  INITIAL SEA  SEASICKNESS DEGRADATION'/,
     3 '  TYPE        OCCURANCE',6X,'TYPE',6X,'OCCURANCE',7X,'STATE',5X,
     4 'TO INITIAL COMPETANCE'//I5,10X,I2,11X,I2,10X,I2,12X,I2,15X,F7.4)
 9620 FORMAT(I5,9X,I3,10X,I3,9X,I3)
 9621 FORMAT(I5,9X,I3)
  684 FORMAT(24X,I6,6X,I6)
      IXDF1=IXDF+1
      IDIFF=IQMAX-KMAX
      IF(IDIFF) 695,696,699
  699 WRITE(6,9621)(J,IDF(J),J=IXDF1,IQMAX)
      GO TO 696
  695 WRITE(6,684) (J,IDE(J),J=IXDF1,KMAX)
  696 CONTINUE
      CALL DINPUT                                                       MAIN2600
      IF(ND .GE. IND(4))  WRITE(6,8502)                                 MAIN2610
 8502 FORMAT(1H1)                                                       MAIN2620
C***IDENTIFY FAILURES AND EMERGENCIES FOR THE DAY                        MAIN2630
C***AND COMPUTE NEXT OCCURRENCE FOR EACH                                 MAIN2640
  700 NR = 0                                                            MAIN2650
      KK = NOSE                                                         MAIN2660
      DO 710 I = 1,IQMAX                                                MAIN2670
      IF (IDF(I).NE.ND) GO TO 710                                       MAIN2680
      IDFFF(I)=ND
      NR = NR+1                                                         MAIN2690
      KK = KK+1                                                         MAIN2700
      IEVENT(KK)=200+(I-1)*12  + 1                                      MAIN2710
      II=RELH(I)*ALOG(UNIFM1(0.0))-.5                                   MAIN2720
      IF(II.EQ.0)II=-1                                                  MAIN2730
      IDF(I) = IDF(I)-II                                                MAIN2740
  710 CONTINUE                                                          MAIN2750
  750 NE = 0                                                            MAIN2760
      DO 760 I = 1,KMAX                                                 MAIN2770
      IF (IDE(I).NE.ND) GO TO 760                                       MAIN2780
      NE = NE+1                                                         MAIN2790
      KK = KK+1                                                         MAIN2800
      IEVENT (KK) = I + 560                                             MAIN2810
      II =         NDRE(I) * ALOG (UNIFM1(0.0)) - 0.5                   MAIN2820
      IF(II.EQ.0)II=- 1                                                 MAIN2830
      IDE (I) = IDE(I) - II                                             MAIN2840
```

```
  760 CONTINUE
      NUMFAM = 0
      NOIFT = 0
      IST = (ICSS + 1) /10.
      DO 697 I=1,NOSE
      IF (NN + NOIFT .GE. 30) GO TO 697
      NOIF = 0
      IF (IFOI (I) .NE. 1) GO TO 697
      NUMFAM = NUMFAM + 1
      IF (NOIFT .GT. 10) GO TO 697
C
C     ACCESS TYPE DATA FROM DISC
      ITEM=IETYP(I)
      READ(12'ITEM,ERR=3000) ADURIO
C
      IF (NIOR .EQ. 0) GO TO 697
C
      II=IOR(NIOR)
      IF(IDFFF(II).EQ.ND) GO TO 697
      DO 698 INIQ = 1,NIOR
      IF (NOIF .EQ. 1) GO TO 698
      RV2 = UNIFM1 (0.0)
      BTEM = 0.001
      IF(LODM.GT. 3) BTEM=0.01
      IF(LODM.GT.6) BTEM=0.03
      ATEM = FUNC(BTEM,RV2,IST)
      IF ( ATEM .LT. UNIFM1(0.0)) GO TO 698
      NOIF = 1
      KK = KK + 1
C
C     COUNTER
C
      NOIFT = NOIFT + 1
C
C     WHICH REPAIR SEQUENCE
C
      IEVENT(KK)=200+12*(IOR(NIOR)-1)+1
      IDFFF(II)=ND
C
C     WHICH SCHEDULED EVENT HAS AN OIF
C
      IOIF (NOIFT) = I
  698 CONTINUE
  697 CONTINUE
C
C     NR IS NUMBER OF REPAIR FAMILIES
C
      NR = NR + NOIFT
      NOSE1 = 0
      NTE = NR + NE + NOSE
      DO 770 I =1, NOSF
```

```
      IF ( IFOI(I) .NE. 1) GO TO 770
      IEVENT (II) = I
      NOSE1 = NOSE1 + 1
  770 CONTINUE
C
C     RANDOMLY ASSIGNS REPAIRS THEN EMERGENCIES TO TASK SEQUENCE AND
C     THEN FILLS IN SCHEDULED EVENTS TO QUEUE IN ORDER OF INPUT
C
C***  GENERATE POINTERS FOR EVENTS FOR THIS DAY
  775 DO 780 I = 1,NTE
  780 PTR(I) = 0
      JJ = NOSE  + 1
      TEM1 = NTE-1
      DO 810 I = JJ,NTE
      II = UNIFM1(0,0)*TEM1+1.0
      IF(PTR(II)) 785,805,785
  785 KK = II
  790 II = II+1
      IF (II.GT.NTE) GO TO 795
      IF(PTR(II)) 790,805,790
  795 II = KK
  800 II = II-1
      IF (PTR(II).NE.0) GO TO 800
  805 KK = IEVENT(I)
      PTR(II) = KK
      INVS(KK) = II+1
  810 CONTINUE
      KK = 1
      DO 820 I=1,NOSE
      IF (IFOI(I) .NE. 1) GO TO 820
  815 IF(PTR(KK) .EQ. 0)  GO TO 818
      KK = KK+1
      GO TO 815
  818 PTR(KK) = I
  820 CONTINUE
C
C     KOUNT IS INCREMENT FOR NPTR TO INCLUDE OIF AND FAMILY MEMBERS
C
      IGAP = 0
      KOUNT = 0
      DO 831 I=1,NTE
      IPTR = PTR (I)
      IF (IPTR .NE. 0) GO TO 841
      IGAP = IGAP + 1
      GO TO 831
  841 CONTINUE
      NPTR (I + KOUNT - IGAP) = IPTR
      IF (IPTR .GE. 561) GO TO 831
C
C     ISW1 = 0 SCHEDULED AND REPAIR EVENTS
C     ISW1 = 1 REPAIR EVENTS FOR OIF
```

```
C
      ISW1 = 0
  835 IF (IPTR .GT. 200) GO TO 842
      INIF = NIF (IPTR) - 1
      IF (INIF .EQ. 0) GO TO 834
      GO TO 843
  842 INIF = IRE ((IPTR-200) /12 + 1) - 1
      IF (INIF .EQ. 0) GO TO 834
  843 DO 832 J=1,INIF
      KOUNT = KOUNT + 1
      NPTR (I + KOUNT - IGAP) = IPTR  + J
  832 CONTINUE
C
C     CHECK IF SECOND TIME THROUGH
C
  834 IF (ISW1 .EQ. 1) GO TO 831
      IF (NOIFT .EQ. 0) GO TO 831
      IF (IPTR .GT. 200) GO TO 831
      ISW1=1
      DO 833 J=1,NOIFT
      IF (IPTR .NE. IOIF(J) ) GO TO 833
C
C     HAVE AN OIF
C
      KOUNT = KOUNT + 1
      IPTR= IEVENT(NTE+J)
      GO TO 835
  833 CONTINUE
  831 CONTINUE
C
C     THIS LOOP COUNTS TOTAL NO. OF EVENTS
       DO 8 I=1,570
      IF(NPTR(I).EQ.0 ) GO TO 9
    8  CONTINUE
    9  NTE=I-1
C
      DO 821  I=1,NTE
      IF(NPTR(I).LE.200) GO TO 826
  821  CONTINUE
  826 KK=561
      NX(1,KK)=NPTR(I)
      PRB(1,KK)=1.1
      DO 824 I=1,NTE
      K=NPTR(I)
      INVS(K)=I +1
      IF(K.LE.200) GO TO 823
      IF(K.GT.560) GO TO 822
      IF (IRE((K-201) /12 + 1 ) .EQ. 1 .OR. IFOI(K) .EQ. 2) GO TO 822
      GO TO 824
  822  NX(1,K)=NX(1,KK)
       NX(2,K)=NX(2,KK)
```

```
      NX(3,K)=NX(3,KK)
      PRB(1,K)=PRB(1,KK)
      PRB(2,K)=PRB(2,KK)
      PRB(3,K)=PRB(3,KK)
      GO TO 824
  823 KK=K
  824 CONTINUE
  830 IEIE = 1
  840 IE = NPTR (IEIE)
      WRITE(6,845) (JI,CDT(JI),JI=1,IQMAX)
  845 FORMAT(1H1,'INTERMITTANT DOWN TIME',/,'   IQ    CDT(IQ)',//,
     1 (I5,F10.2))
      WRITE(6,846)(JI,TPCOM(JI),JI=1,IC)
  846 FORMAT(1H1,'MAN      COMPETANCE',/,'(IC)  TPCOM(M)  TSCOM(M)',/,
     1 (I3,2F10.2))
      IFIRST = 1
C***   RESETS FOR EACH EVENT
  850 IRI = 0
      IQ=0
      ITRY = 0
      IGNOR = 0
      USH=0.
C***   DETERMINE WHETHER EVENT SHOULD BE IGNORED
C
C      ACCESS TYPE DATA FROM DISC
C******   EMERGENCY IF TYPE= -1
      ITEM=IETYP(IE)
      IF(ITEM.EQ.(-1)) GO TO 851
      READ(12'ITEM,ERR=3000) ADURIO
      GO TO 854
  851 ADUR=ART(IE-560)
      ASD=ASDE(IE-560)
      IESS=IESSE(IE-560)
      LODM=LODME(IE-560)
      KE=2
      INT=1
      NIGR=0
      IH=IHE(IE-560)
      ICLASS=5
      DO 852  I=1,10
      NREQ(I)=NREQE(I,IE-560)
      IRC(I)=IRCE(I,IE-560)
      IRC1(I)=IRCE1(I,IE-560)
  852 IEC(I)=IECE(I,IE-560)
C
  854 IF ( IE .GT. 200) GO TO 862
      IF (IESS .GE. IET) GO TO 855
      IEIND = 1
      GO TO 1815
  855 KK = TS(IE)
      IGIND=4
```

```
      DO 860 I = 1,LMAX                                                   MAIN4820
      IF(KONC(I) .LT. KONT(I,KK))  GO TO 1815                             MAIN4830
  860 CONTINUE                                                            MAIN4840
      ISIND=5                                                             MAIN4850
      KK=TS1(IE)                                                          MAIN4860
      DO 861 I=1,LMAX1                                                    MAIN4870
      IF(KONC1(I)    .LT.KONT1(I,KK)) GO TO 1815                          MAIN4880
  861  CONTINUE                                                           MAIN4890
C                                                                         MAIN4900
C     COMPUTE NUMBER OF HOURS PEP SHIFT                                   MAIN4910
C                                                                         MAIN4920
  862 SFTHRS = 24./FLOAT(NDS)                                             MAIN4930
C                                                                         MAIN5110
C     DETERMINE EARLIEST SHIFT JOB CAN BE STARTED ON AND LATEST TIME BY   MAIN5120
C    1 JOB MUST BE COMPLETED                                              MAIN5130
C                                                                         MAIN5140
      JJ=IPE(IE)
      III = (AMAX1(ZC(JJ),ST(IE)))/SFTHRS + 1.0                           MAIN5150
C     LSHIFT = 0--FIRST SORT THROUGH ALL POSSIBLE SHIFTS                  MAIN5170
C     LSHIFT = 1-- SECOND SORT WITH DESIRED SHIFT                         MAIN5180
C                                                                         MAIN5190
      LSHIFT = 0                                                          MAIN5200
C***   IS  IS TOTAL NUMBER OF MEN REQUIRED FOR EVENT                      MAIN5290
C     WRITE(6,1066) KTEMP,III,JNDS                                        MAIN5300
C1066 FORMAT(1H04I10)                                                     MAIN5310
      JI=III
      LSHIFT=0
      IS = 0                                                              MAIN5320
      IRI =0                                                              MAIN5330
      ISNOR =0                                                            MAIN5340
      DO 880 I = 1,NTMAX                                                  MAIN5350
  880  NREQT(I)=NNEQ(I)                                                   MAIN5360
C***   SELECTION OF PEPSONNEL FOR EACH TYPE                               MAIN5370
C***   KIND = 0  WHEN SELECTING PRIMARY SPECIALTIES                       MAIN5380
C***   KIND = 1  WHEN SELECTING SECONDARY SPECIALTIES                     MAIN5390
      DO 885 I=1,IC                                                       MAIN5400
  885 MENSN(I)=0                                                          MAIN5410
      KIND = 0                                                            MAIN5420
      II = 1                                                              MAIN5430
      KA = 0                                                              MAIN5440
      IF (INT      .EQ.2) GO TO 1020                                      MAIN5450
  900 IF (NREQT(II).NE.0) GO TO 925                                       MAIN5460
  910 IF (II.EQ.NTMAX) GO TO 920                                          MAIN5470
      II = II+1                                                           MAIN5480
      KA = 0                                                              MAIN5490
      GO TO 900                                                           MAIN5500
  920 IF (IPI.EQ.0) GO TO 1060                                            MAIN5510
       IF(KIND) 1060,1020,1060                                            MAIN5520
  925 IF (KA.NE.0) GO TO 990                                              MAIN5530
       TEM1=TL(IE)                                                        MAIN5540
      LL = KIND*20                                                        MAIN5550
```

```
      DO 950 I = 1,IC                                                   MAIN5560
      LL = LL+1                                                         MAIN5570
       IF(MCHSN(I).NE.0) GO TO 950                                      MAIN5580
C                                                                       MAIN5590
C     TRIVIAL CASE IS IDS(JI ,1) = 1 FOR ALL JI                         MAIN5600
C     THIS CASE IS ORIGINAL --NO SHIFT--MODEL                           MAIN5610
C                                                                       MAIN5620
      IF (IE .GT. 200) GO TO 930                                        MAIN5630
       IF (IDS(JI,I) .NE. 1) GO TO 950                                  MAIN5640
  930 IF(IPSS(LL).NE.II) GO TO 950
       IF(Z(I).GT.TEM1) GO TO 950                                       MAIN5780
      IF (TW(I).GT.WORK2) GO TO 950                                     MAIN5790
      KA = KA+1                                                         MAIN5800
      MAVAIL(KA) = I                                                    MAIN5810
       CALR=PWR(I)                                                      MAIN5820
      TEM2 = IEC(II)                                                    MAIN5830
      IF (CALR.LE.TEM2) GO TO 935                                       MAIN5840
      CALR = 1.0                                                        MAIN5850
      GO TO 940                                                         MAIN5860
  935 CALR = CALR/TEM2                                                  MAIN5870
  940 TAVAIL(KA) = 1000.0-10.0*TW(I)*CALR*TPSCON (LL)                   MAIN5880
  950 CONTINUE                                                          MAIN5890
      IF (KA.NE.0) GO TO 960                                            MAIN5900
  955 IPI = 1                                                           MAIN5910
      IF (KIND.EQ.0) GO TO 910                                          MAIN5920
  958  USH = USH + ADUR * FLOAT(NREQT(II) )
      GO TO 910                                                         MAIN5950
  960 KK = KA-1                                                         MAIN5960
      IF (KK.EQ.0) GO TO 990                                            MAIN5970
      DO 980 I = 1,KK                                                   MAIN5980
      LL = KA-I                                                         MAIN5990
      DO 970 J = 1,LL                                                   MAIN6000
      TEM1 = TAVAIL(J)                                                  MAIN6010
      IF (TEM1.LE.TAVAIL(J+1)) GO TO 970                                MAIN6020
      TAVAIL(J) = TAVAIL(J+1)                                           MAIN6030
      TAVAIL(J+1) = TEM1                                                MAIN6040
      NN = MAVAIL(J)                                                    MAIN6050
      MAVAIL(J) = MAVAIL(J+1)                                           MAIN6060
      MAVAIL(J+1) = NN                                                  MAIN6070
  970 CONTINUE                                                          MAIN6080
  980 CONTINUE                                                          MAIN6090
  990 IF (KA.EQ.0) GO TO 955                                            MAIN6100
      NN = MAVAIL(KA)                                                   MAIN6110
      KA = KA-1                                                         MAIN6120
       IF((IE.GE.561).OR.(IESS    .EQ.100)) GO TO 1000                  MAIN6130
      IF (TW(NN)+ADUR    .LE.WORK1) GO TO 1000                          MAIN6140
  995  IF(KIND.EQ.1) GO TO 958                                          MAIN6150
      IPI = 1                                                           MAIN6160
      GO TO 910                                                         MAIN6170
 1000  IF(TW(NN).GT.WORK2) GO TO 995                                    MAIN6180
       IG=IG+1                                                          MAIN6190
```

```
      RCHSN(NN)=1                                                       MAIN6200
      MA(IG,II) = NN                                                    MAIN6210
      MAT(IG) = NN                                                      MAIN6220
      ITYPE(NN) = II                                                    MAIN6230
      NREQT(II) = NREQT(II)-1                                           MAIN6240
      IF(KA .NE. 0)  GO TO 900                                          MAIN6250
      IF(NREQT(II)) 955,910,955                                         MAIN6260
C                                                                       MAIN6270
C     RESET FOR SECONDARY SEARCH                                        MAIN6280
C                                                                       MAIN6290
 1020 KIND = 1                                                          MAIN6300
      II = 1                                                            MAIN6310
      KA=0
      GO TO 900                                                         MAIN6320
C***  SELECT LEADER                                                     MAIN6330
 1060 CONTINUE                                                          MAIN6340
      IF(LSHIFT.EQ.1) GO TO 1063
      ITEM=0
      DO 1061 I=1,NTMAX
 1061 ITEM=ITEM+NREQ(I)
      IF(USH.LT.USHLIM*FLOAT(ITEM)*ADUR) GO TO 1063
      IF(JI.GE.NDS) GO TO 1063
      USH=0
      JI=III+1
      LSHIFT=1
      KIND=0
      II=1
      KA=0
      GO TO 900
 1063 FLIG=IG
      IF(IG .NE. 0)  GO TO 1065                                         MAIN6620
      IBIND = 2                                                         MAIN6630
      DO 1062 I=1,NTMAX
 1062 IG=IG+NREQT(I)
      USH=USH+ADUR*FLOAT(IG)
      GO TO 1015                                                        MAIN6670
 1065 LI = MAT(1)                                                       MAIN6680
      JJ = ICE(LI)                                                      MAIN6690
      IF (IG.EQ.1) GO TO 1150                                           MAIN6700
      DO 1080 I = 2,IG                                                  MAIN6710
      KK = MAT(I)                                                       MAIN6720
       IF(ICE(KK)-JJ) 1075,1070,1080                                    MAIN6730
 1070 IF (TPCOM(KK) .LE. TPCOM(LI)) GO TO 1080                          MAIN6740
 1075 LI = KK                                                           MAIN6750
      JJ = ICE(KK)                                                      MAIN6760
 1080 CONTINUE                                                          MAIN6770
C                                                                       MAIN6780
C     DETERMINE Z1 = EARLIEST TIME ALL GROUP IS AVAILABLE               MAIN6790
C                                                                       MAIN6800
 1150 KK = 0                                                            MAIN6810
      Z1 = 0.0                                                          MAIN6820
```

```
      DO 1160 I = 1,IG
      JJ = MAT(I)
 1160 Z1 = AMAX1(Z1,Z(JJ))
C.... DETERMINE EARLIEST TIME WHEN THE EVENT CAN BEGIN
      JJ = IPE(IE)
      TEM2=0.0
      IF(JJ.NE.0) TEM2=ZC(JJ)
C     ATEM = KTEMP *SFTHRS
C     Z2=AMAX1(Z1,TEM2,ST(IE),ATEM)
      Z2=AMAX1(Z1,TEM2,ST(IE))
      IF(Z2.LT.TL(IE).OR.IE.GT.560) GO TO 1162
C     IF(Z2 .LT. TL(IE))  GO TO 1162
      IGIND = 3
      USH=USH+ADUN*FLIG
      GO TO 1815
C
 1162 DO 1165 I = 1,IG
      JJ = MAT(I)
C..... IS A NON-SCHEDULED REST OR SLEEP REQUIRED DUE TO START TIME
      WH(JJ) = Z2-Z(JJ)
      IF (WH(JJ).NE.0.0) KK = 1
 1165 CONTINUE
       IF(KK.EQ.0) GO TO 1250
       TEM2=CN*.5
C..... IS THE TIME SINCE LAST EVENT LONG ENOUGH TO ALLOW SLEEP
      DO 1260 I=1,IG
      JJ = MAT(I)
       IF(WH(JJ).LT.TEM2) GO TO 1240
C...     IS SLEEP QUOTA FOR DAY USED
      IF(DS(JJ) .GE. MAXSL)  GO TO 1240
C...     OR -- IS FATIGUE UNDER THRESHOLD
      IF(FAT(JJ) .LE. TFAT)  GO TO 1240
C...     NEITHER -- SUM SLEEP THIS DAY FOR EACH M IN G
       TEM1=MAXSL-DS(JJ)
C...     LIMIT WH(JJ)  SO THAT DS .LE. MAXSL
       DS(JJ)=AMIN1(DS(JJ)+WH(JJ)-.5,MAXSL)
C...     CALCULATE TIME FATIGUE DUE TO SLEEP RELIEF FOR EACH M IN G
       TEM1=AMIN1(WH(JJ),TEM1)-.5
      IF(TEM1 .LE. 9.0)  GO TO 1205
 1200 FAT(JJ) = 0.0
      GO TO 1220
 1205 IF(TEM1 .LT. 1.0)  GO TO 1210
      FAT(JJ) = FAT(JJ)*((138.0-19.0*TEM1)/140.0+0.2*UNIFM1(0.0))
      GO TO 1220
 1210 FAT(JJ) = FAT(JJ)*(0.9-0.05*TEM1+0.2*UNIFM1(0.0))
 1220 IF(FAT(JJ) .LT. 0.0)  FAT(JJ) = 0.0
      IF(FAT(JJ) .GT. 1.0)  FAT(JJ) = 1.0
      ABAL(JJ) = 0.0
      TEM1 = FAT(JJ)
      IF(TEM1 .GT. 0.9)  GO TO 1225
      IF(TEM1 .GT. 0.15)  GO TO 1224
```

```
      HSLS(JJ) = 53.333333 * FAT(JJ)                                   MAIN7330
      GO TO 1260                                                       MAIN7340
 1224 HSLS(JJ) = 14.666667*TEM1+5.8                                    MAIN7350
      GO TO 1260                                                       MAIN7360
 1225  HSLS(JJ)=AMAX1(310.0*TEM1-260.0,0.0)                            MAIN7370
      GO TO 1260                                                       MAIN7380
C***     ADJUST HOURS SINCE LAST SLEEP FOR THIS M                      MAIN7390
 1240 HSLS(JJ) = HSLS(JJ) + WH(JJ)                                     MAIN7400
 C       CALCULATE FATIGUE BUILDUP FOR THIS MAN DUE TO REST            MAIN7410
      FAT(JJ) = FBUILD(HSLS(JJ))                                       MAIN7420
 1260 CONTINUE                                                         MAIN7430
C***   CALCULATE PHYSICAL CAPABILITY OF EACH MAN IN GROUP              MAIN7440
C***  SAVE MAX PHYS CAPABILITY FOR EACH MAN                            MAIN7450
 1280 GRCC = 0.0                                                       MAIN7460
      DO 1295 I = 1,IG                                                 MAIN7470
      JJ = MAT(I)                                                      MAIN7480
      KK = IPS(JJ)                                                     MAIN7490
       TEM2=IEC(KK)    /PWR(JJ)                                        MAIN7500
      IF (TEM2.GE.1.0) GO TO 1285                                      MAIN7510
      EXER = 1.0                                                       MAIN7520
      GO TO 1290                                                       MAIN7530
 1285 EXER = (ZPC-TEM2)/(ZPC-1.0)                                      MAIN7540
      IF(EXER.LT.0.)WRITE(6,9900) ND,IE,PCC
 1290 TEM1=(ACAL(JJ)/CAL(JJ))**2                                       MAIN7550
      TEM1 = PC(JJ)*PI(JJ)*(1.0-(1.0-K1)*TEM1)*EXER*(1.0-0.1*FAT(JJ))  MAIN7560
      IF (TEM1.LT.0.0) TEM1     = 0.0                                  MAIN7570
      IF (TEM1.GT.2.0) TEM1     = 2.0                                  MAIN7580
       MPCC(JJ)=AMAX1(MPCC(JJ),TEM1)                                   MAIN7590
       RCC(JJ)=TEM1                                                    MAIN7600
 1295 GPCC = GPCC+TEM1                                                 MAIN7610
      GPCC = GPCC/FLIG                                                 MAIN7620
C***    CALCULATE GROUP STRESS THRESHOLD AND GROUP STRESS              MAIN7630
      GSTRM=0.0                                                        MAIN7640
      DO 1370 I = 1,IG                                                 MAIN7650
      JJ = MAT(I)                                                      MAIN7660
 1370 GSTRM = GSTRM+STRM(JJ)                                           MAIN7670
      GSTRM = GSTRM/FLIG                                               MAIN7680
 1375  IF(IE.GE.560) GO TO 1377                                        MAIN7690
      GSTR = (ADUR     *(.875+LODM     *.025))/(TL(IE)-Z2)             MAIN7700
       GO TO 1378                                                      MAIN7710
 1377  GSTR=GSTRM                                                      MAIN7720
 1378 IF (GSTR.GT.5.0) GSTR = 5.0                                      MAIN7730
       IF(GSTR.LT.1.0) GSTR=1.0                                        MAIN7740
C***    CALCULATIONS FOR PERFORMANCE TIME AND END TIME                 MAIN7750
 1300 IF(ASD      .NE.0.0) GO TO 1380                                  MAIN7760
      IF (KE      .NE.1) GO TO 1310                                    MAIN7770
      IF((Z2+ADUR      ) .GT. TL(IE))  GO TO 1320                      MAIN7780
      PT(IE) = ADUR                                                    MAIN7790
      ZC(IE) = TL(IE)                                                  MAIN7800
      GO TO 1550                                                       MAIN7810
 1310 PT(IE) = ADUR                                                    MAIN7820
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      ZC(IE) = Z2+PT(IE)                                                MAIN7830
      GO TO 1550                                                        MAIN7840
 1320 PT(IE) = TL(IE)-Z2                                                MAIN7850
      ZC(IE) = TL(IE)                                                   MAIN7860
      GO TO 1550                                                        MAIN7870
 1380 PAF = 1.0                                                         MAIN7880
C***    CALCULATE GROUP PERFORMANCE, GROUP ASPIRATION LEVEL             MAIN7890
      GPERF = 0.0                                                       MAIN7900
      GASP = 0.0                                                        MAIN7910
      DO 1390 I = 1,IG                                                  MAIN7920
      JJ = MAT(I)                                                       MAIN7930
      GPERF = GPERF+PERF(JJ)                                            MAIN7940
 1390 GASP = GASP+CASP(JJ)                                              MAIN7950
      GPERF = GPERF/FLIG                                                MAIN7960
      GASP = GASP/FLIG                                                  MAIN7970
C***   SELECT ONE OF FIVE CASES  COMPARING GASP WITH GPERF              MAIN7980
C***          AND  GSTR WITH GSTRM                                      MAIN7990
      TEM1 = GASP-GPERF                                                 MAIN8000
      IF (ABS(TEM1).LE.0.02) GO TO 1460                                 MAIN8010
      TEM2 = GSTR-GSTRM                                                 MAIN8020
      IF (TEM1.GT.0.0) GO TO 1395                                       MAIN8030
      IF (TEM2) 1410,1450,1450                                          MAIN8040
 1395 IF (TEM2) 1400,1430,1430                                          MAIN8050
 1400 PAF = 1.0-0.4*TEM1                                                MAIN8060
      GO TO 1460                                                        MAIN8070
 1410 DO 1420 I = 1,IG                                                  MAIN8080
      JJ = MAT(I)                                                       MAIN8090
       TEM3=PERF(JJ)-CASP(JJ)                                           MAIN8100
       IF(TEM3.LE.0.0) GO TO 1420                                       MAIN8110
       TEM3=CASP(JJ)+0.1*TEM3*DNORM1(0,0)                               MAIN8120
      IF (TEM3.GT.1.0) TEM3 = 1.0                                       MAIN8130
       CASP(JJ)=TEM3                                                    MAIN8140
 1420  CONTINUE                                                         MAIN8150
      GO TO 1460                                                        MAIN8160
 1430 DO 1440 I = 1,IG                                                  MAIN8170
      JJ = MAT(I)                                                       MAIN8180
 1440 CASP(JJ) = PERF(JJ)                                               MAIN8190
      PAF = 1.0+0.4*TEM1                                                MAIN8200
      GO TO 1460                                                        MAIN8210
 1450 GSTR = 0.9*GSTRM                                                  MAIN8220
C***    CALCULATE PERFORMANCE TIME                                      MAIN8230
 1460 IF (GPCC.GE.1.0) GO TO 1470                                       MAIN8240
      SF = 2.0-GPCC                                                     MAIN8250
      GO TO 1480                                                        MAIN8260
 1470 SF = 1.5-GPCC*0.5                                                 MAIN8270
 1480 TEM3 = 0.0                                                        MAIN8280
      DO 1490 I = 1,IG                                                  MAIN8290
      JJ = MAT(I)                                                       MAIN8300
 1490 TEM3 = TEM3+PACE(JJ)                                              MAIN8310
      GPACE = TEM3/FLIG*SF*PAF                                          MAIN8320
C                                                                       MAIN8330
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C       TEST FOR REPAIRS                                                MAIN8340
C                                                                       MAIN8350
        IF (IE ,LT, 201) GO TO 1492                                     MAIN8360
        IF ( IE ,GT, 560) GO TO 1492                                    MAIN8370
        TEM1 = 1 + (ASD *ASD)/(ADUR * ADUR)                             MAIN8380
        V = EXP(ALOG(ADUR/SQRT(TEM1)) + DNORM1(0.0) * SQRT (ALOG(TEM1)))  MAIN8390
        GO TO 1493                                                      MAIN8400
 1492   V= ADUR + DNORM1(0.0) * ASD                                     MAIN8410
 1493 CONTINUE                                                          MAIN8420
      ADUR 2 = ADUR/2.                                                  MAIN8430
      V = AMAX1(ADUR2,V)                                                MAIN8440
C                                                                       MAIN8450
      IF (TEM2,GE,0,0) GO TO 1500                                       MAIN8460
      TEM3 = (GSTR-1,0)/(GSTRM-1,0)                                     MAIN8470
      PT(IE) = GPACE * V *((-  2,3075 * TEM3) + (3,4722 * TEM3 * TEM3)  MAIN8480
     1 + (-1,829 * TEM3 * TEM3 * TEM3)+1)                               MAIN8490
C     PT(IE) = GPACE*V*(1,0+TEM3*(-2,35075+TEM3*(3,4722-1,329*TEM3)))   MAIN8500
      GO TO 1535                                                        MAIN8510
 1500 IF (TEM2,GT,1,0) GO TO 1510                                       MAIN8520
      PT(IE)=GPACE*((2,0*TEM2+1,0)*V-TEM2*ADUR)                         MAIN8530
      GO TO 1535                                                        MAIN8540
 1510 PT(IE) = (3,0*V-ADUR    )*GPACE                                   MAIN8550
C         LIMIT PT(IE)                                                  MAIN8560
 1535 IF(PT(IE) ,GE, 0,0)  GO TO 1537                                   MAIN8570
      PT(IE) = 0,0                                                      MAIN8580
      GO TO 1539                                                        MAIN8590
 1537 TEM1 = 4,0*ADUR                                                   MAIN8600
      IF(PT(IE) ,LE, TEM1)  GO TO 1539                                  MAIN8610
      PT(IE) = TEM1                                                     MAIN8620
C***    CALCULATE REAL TIME OF EVENT COMPLETION                         MAIN8630
 1539 ZC(IE) = Z2 + PT(IE)                                              MAIN8640
      IF(ZC(IE),LE,TL(IE)) GO TO 1545                                   MAIN8650
      PT(IE)=TL(IE)-Z2                                                  MAIN8660
      USH=USH+FLIG*(ZC(IE)-TL(IE))
      ZC(IE)=TL(IE)                                                     MAIN8680
 1545 IF(ZC(IE),LE,24,0) GO TO 1550                                     MAIN8690
      PT(IE) = 24,0-Z2                                                  MAIN8700
      ZC(IE) = 24,0                                                     MAIN8710
 1550 CONTINUE                                                          MAIN8720
C***    UPDATE HSLS, TW,Z,CCAL,ACAL,IDC FOR EACH MAN                    MAIN8730
 1560 ITRY = ITRY+1                                                     MAIN8740
      IF(IE,GT,560) GO TO 1566                                          MAIN8750
      DO 1565 I=1,NIQR                                                  MAIN8760
      ITEM=IQR(I)                                                       MAIN8770
      IF(IE,GE,201) GO TO 1562                                          MAIN8780
      CUT(ITEM)=CUT(ITEM)+PT(IE)                                        MAIN8790
      GO TO 1565                                                        MAIN8800
 1562 CDT(ITEM)=CDT(ITEM)+PT(IE)                                        MAIN8810
      SCDTIQ=SCDTIQ+PT(IE)
      WRITE(6,8009) SCDTIQ,CDT(ITEM)                                    MAIN8830
 8009 FORMAT(' ***** SCDTIQ=',F7.2,' CDT(ITEM)=',F7.2)                  MAIN8840
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      CART (ITEM) = CART (ITEM) + ADUR
 1565  EPL(ITEM)=CUT(ITEM)/(CUT(ITEM)+CDT(ITEM))
 1566  CONTINUE
      TEM1 = PT(IE)
      TEM2 = ZC(IE)
      TEM3=TEM1
       SIDC=0.0
      DO 1580 I = 1,IG
      JJ = MAT(I)
      HSLS(JJ) = HSLS(JJ)+TEM1
      Z(JJ) = ZC(IE)
      KK = ITYPE(JJ)
      CCAL(JJ) = IEC(KK)    *TEM3*(.95+UNIFM1(0,0)/10.)
      ACAL(JJ) = ACAL(JJ)+CCAL(JJ)
      IDC(JJ) = IDC(JJ)+CCAL(JJ)
      TW(JJ) = TW(JJ)+TEM1
       IF(KK.EQ.IPS(JJ)) GO TO 1579
       CLSDTA(7,ICLASS)= CLSDTA(7,ICLASS) + PT(IE)
       TWS(JJ)=TWS(JJ)+PT(IE)
       GO TO 1580
 1579 TWP(JJ)=TWP(JJ)+PT(IE)
       CLSDTA(6,ICLASS)= CLSDTA(6,ICLASS) + PT(IE)
 1580 SIDC = SIDC + CCAL(JJ)
       IF(SIDC.LE.SIDCMX) GO TO 1582
       SIDCMX=SIDC
       IDCMX=IE
 1582 TEM2=LODM     *TEM1
C***    ACCUMULATE CML AND SAVE MAX
      IF(CMLMX.GE.TEM2) GO TO 1585
      CMLMX=TEM2
      ICML=IE
 1585 CML=CML+TEM2
C***    EVENT HAZARD AND SUM FOR DAY (TEM)
      EH = TEM1*IH
      TEM = TEM+EH
C***    CALCULATE PERFORMANCE ADEQUACY
 1600  IF(ITRY.GT.1) GO TO 1645
      IF (GSTRM.GE.GSTR) GO TO 1610
      IF (GSTR.LE.5.0) GO TO 1620
      ES = 0.0
      GO TO 1630
 1610 ES = (1.0-BE)/(GSTRM-1.0)*GSTR+BE
      GO TO 1630
 1620 ES = (5.0-GSTR)/(5.0-GSTRM)
 1630 TEM1 =TPCOM(LI)
      IF (ITYPE(LI).NE.IPS(LI)) TEM1 =TSCOM(LI)
      EG = 2.0*TEM1
      EA = 2.0*CASP(LI)
      DO 1640 I = 1,IG
      JJ = MAT(I)
      IF (ITYPE(JJ).NE.IPS(JJ)) TEM2 =TSCOM(JJ)
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```
      TEM2 =TPCOM(JJ)
      EC = EC+TEM2
 1640 EA = EA+CASP(JJ)
      TEM2 = FLIG+2,0
      ES = EC/TEM2
      EA = EA/TEM2
       EF=AMIN1(1,0,GPCC)
       GO TO 1647
 1645  EC=AMIN1(EC+,2,1,0)
 1647 TEM1 = EF+EA
C     WRITE (6,1650) PA,TEM1,ES,EF,EA,EC
      PA = SQRT((3,0*EC*(TEM1+ES)+ES*TEM1+EF*EA)/12,0)
C     WRITE (6,1650) PA,TEM1,ES,EF,EA,EC
       APA=APA+PA
C***   COMPUTE EFFICIENCY FACTOR
C
      SEF = SEF + (PA*FLOAT(IESS     ))/(CASP(LI)*K7)
C     WRITE (6,1650) PA,CASP(LI),K7 ,SEF
C1650 FORMAT(5H SEF 6F10,5)
C     WRITE (6,1655) IESS
C1655 FORMAT (5H IESS 5I10)
       IS(E)=IS(E)+IESS
C***    CALCULATE TIME FATIGUE AND PHYS CAP FOR ALL MEN IN GROUP
 1700 GPCC=0,0
      DO 1740 I = 1,IG
      JJ = MAT(I)
      FAT(JJ) = FBUILD(MSLS(JJ))
      KK = ITYPE(JJ)
       TEM2=IEC(KK)    /PWR(JJ)
      IF (TEM2,GE,1,0) GO TO 1725
      EXER = 1,0
      GO TO 1730
 1725 EXER = (ZPC-TEM2)/(ZPC-1,0)
      IF(EXER,LT,0,)WRITE(6,9900) ND,IF,PCC
 1730 TEM1=(ACAL(JJ)/CAL(JJ))**2
      TEM1 = PC(JJ)*PI(JJ)*(1,0-(1,0-K1)*TEM1)*EXER*(1,0-0,1*FAT(JJ))
      IF (TEM1,GT,2,0) TEM1 = 2,0
      IF (TEM1,LT,0,0) TEM1 = 0,0
       MPCC(JJ)=AMAX1(MPCC(JJ),TEM1)
      PCC(JJ) = TEM1
 1740 GPCC = GPCC+TEM1
      GPCC = GPCC/FLIG
C***    CALCULATE NEW CONSUMABLE LEVELS
      TEM1 = PT(IE)
      DO 1750 I = 1,LMAX
       KONE(I)=IRC(I     )*TEM1
      KONC(I) = KONC(I)-KONE(I)
 1750 CONTINUE
      DO 1752 I=1,LMAX1
      KONE1(I)=IRC1(I)
      KONC1(I)=KONC1(I)-KONE1(I)
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 1752  CONTINUE                                                       MAIN9860
C***     NO CONSUMABLES USED UP                                        MAIN9870
C***     DETERMINE SUCCESS OR FAILURF FOR EVENT                        MAIN9880
 1755  SUCC = YU                                                       MAIN9890
        FDIFF=CASP(LI)*K7-PA                                           MAIN9900
        IF(FDIFF.LT.0.0) SUCC=ESSS                                     MAIN9910
        CLSDTA(1,ICLASS)= CLSDTA(1,ICLASS) + 1                         MAIN9920
        CLSDTA(8,ICLASS)= CLSDTA(8,ICLASS) + PA                        MAIN9930
        CLSDTA(9,ICLASS)= CLSDTA(9,ICLASS) + FDIFF                     MAIN9940
       IF (SUCC.EQ.ESSS) GO TO 1770                                    MAIN9950
        SFDIFF=SFDIFF+FDIFF                                            MAIN9960
C***     FAILED                                                        MAIN9970
       DO 1760 I = 1,IG                                                MAIN9980
       JJ = MAT(I)                                                     MAIN9990
 1760  NOFAIL(JJ) = NOFAIL(JJ)+1.0                                     MAIN0000
        NFALE=NFALE+1                                                  MAIN0010
        CLSDTA(4,ICLASS)= CLSDTA(4,ICLASS) + 1                         MAIN0020
       GO TO 1790                                                      MAIN0030
C***     SUCCESS                                                       MAIN0040
 1770  DO 1780 I = 1,IG                                                MAIN0050
       JJ = MAT(I)                                                     MAIN0060
        NU(JJ)=NU(JJ)+1.0                                              MAIN0070
 1780  NOSUC(JJ)=NOSUC(JJ)+1.0                                         MAIN0080
       KK = 1                                                          MAIN0090
        IF(ITRY.EQ.1) GO TO 1775                                       MAIN0100
        NSUC2=NSUC2+1                                                  MAIN0110
        CLSDTA(3,ICLASS)= CLSDTA(3,ICLASS) + 1                         MAIN0120
         GO TO 1790                                                    MAIN0130
 1775  NSUC1=NSUC1+1                                                   MAIN0140
        CLSDTA(2,ICLASS)= CLSDTA(2,ICLASS) + 1                         MAIN0150
C***     CALCULATE PERFORMANCE LEVEL FOR MEN IN GROUP                  MAIN0160
 1790  DO 1800 I = 1,IG                                                MAIN0170
       JJ = MAT(I)                                                     MAIN0180
       TEM1 = NOSUC(JJ) + NOFAIL(JJ)                                   MAIN0190
       IF(TEM1 .GT. 5.0  .AND.  NOSUC(JJ) .GT. 0.0)                    MAIN0200
     X    PERF(JJ) = NOSUC(JJ)/TEM1                                    MAIN0210
 1800  CONTINUE                                                        MAIN0220
        NPRFM(1)=NPRFM(1)+1                                            MAIN0230
       USHY=USHY+USH
C***     UPDATE MAX STRM FOR TJE DAY                                   MAIN0250
        IF(MAXST.GE.GSTR) GO TO 1805                                   MAIN0260
        MAXST=GSTR                                                     MAIN0270
        MAXSTE=IE                                                      MAIN0280
 1805  GO TO 1820                                                      MAIN0290
C***     COME HERE FOR IGNORE LOGIC                                    MAIN0300
 1815  IGNOR = 1                                                       MAIN0310
        NIGNR=NIGNR+1                                                  MAIN0320
       PY(IE) = 0.0                                                    MAIN0330
        CLSDTA(1,ICLASS)= CLSDTA(1,ICLASS) + 1                         MAIN0340
        CLSDTA(5,ICLASS)= CLSDTA(5,ICLASS) + 1                         MAIN0350
       GO TO 1824                                                      MAIN0360
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C***     TEST FOR PRINT OPTION AFTER UPDATING HOURS SPENT IN ACTIVITIES
 1820   IF(IE.GT.200) GO TO 1821
        HRSS=PT(IE)*FLIG+HRSS
        NPRFH(2)=NPRFH(2)+1
        GO TO 1824
 1821   IF(IE.GT.560) GO TO 1822
        HRSR=PT(IE)*FLIG+HRSR
       REPTM=REPTM+PT(IE)
       WRITE(6,1818) REPTM,PT(IE)
 1818  FORMAT(1H ,'**** REPTM,PT(IE)=',2F10.2)
       IF(IFO1(IE).NE.1) GO TO 1824
        NPRFH(3)=NPRFH(3)+1
        GO TO 1824
 1822  HRSE=HRSE+PT(IE)*FLIG
        NPRFH(4)=NPRFH(4)+1
 1824  IF(ND-IND(4)) 1890,1825,1830
 1825  IF (IE.LT.IND(5)) GO TO 1890
 1830  IF(IE .GT. 560)  GO TO 1850
       IF(IE .GT. 200) GO TO 1840
       KK = 1
       LL = IE
       IF(IGNOR .EQ. 1)  GO TO 1880
       GO TO 1860
 1840  KK = 4
       LL=(IE - 201)/12+1
       IF(IGNOR .EQ. 1)  GO TO 1880
       GO TO 1860
 1850  KK = 7
       LL=IE-560
       IF(IGNOR .EQ. 1)  GO TO 1880
C***     PRINT EVENT DATA
 1860  II = KK+2
       IPET = IPE(IE)
       TEM1 = 0.0
       IF (IPET.NE.0) TEM1 = ZC(IPET)
       DO 1865 I=1,10
       IKONC(I)=KONC(I)
       IKONE(I)=KONE(I)
 1865  CONTINUE
       IF(TITLE(KK).NE.REPAIR) GO TO 1867
C      IF(IEFN(IE).NE.IEFN(IE-1)) IKDF=IKDF+1
C      IF(IDFR(IKDF,1).EQ.0) IKDF=1
       WRITE(6,9861)
      1 LL,IETYP(IE),SUCC,(IDFR(LL,I),I=1,12),
      1 Z1,ST(IE),IPET,
      1 TEM1,Z2,PT(IE),ZC(IE),USH, GSTR,GPCC,GPACE,GASP,PA,FH,
      1 ICLASS,
      2(IKONE(I),I=1,10),(IKONC(I),I=1,10),(KONE1(I),I=1,10),(KONC1(I),I=
      2 1,10)
 9861  FORMAT(1HO/'REPAIR OF EQUIPMENT TYPE',I2,'     EVENT TYPE',I3,4X,
      1 1A6,/,2X,'IDENTIFIER  ',12A6/
```

```
     1 10H MEN AVAIL ,F5.2,15H  START ALLOWED,F6.2,12H PRIOR EVENT,
     2 I4,9H FINISHED,F6.2,13H EVENT STARTS,F6.2,6H LASTS,F6.2,
     3 5H ENDS,F6.2,13H UNMANNED HRS,F7.2/
     4 13H GROUP STRESS,F5.2,9H PHYS CAP,F5.2,5H PACE,F4.1,5H  ASP,F5.2,
     5 8H PERF AD,F6.2,' HAZARD',F4.1,6X,'EVENT CLASS',I5,
     6                          /1X, 22HCONS, USED(UNITS/HR,) 10I6,
     9 /1X,22HCONS, LEFT(UNITS/HR,) 10I6,/1X,22HCONS, USED(UNITS)      ,
     9 10I6,/1X,22HCONS, LEFT(UNITS)      10I6,/
     6 111HMAN TYPE  SPEC   LDR RANK FATIGUE PHYS CAP HRS WRKD CALORIES
     7 CALS+HRS SINCE SLEEP IDLE HRS SLEPT CUM PERF  ASP)
       GO TO 1868
 1867  CONTINUE
       WRITE(6,9860) (TITLE(I),I=KK,II),LL,ND,ITER,SUCC,
     1 Z1,ST(IE),IPET,                                                  MAIN0770
     1 TEM1,Z2,PT(IE),ZC(IE),USH, GSTR,GPCC,GPACF,GASP,PA,TH,
     1 ICLASS,
     2(IKONE(I),I=1,10),(IKONC(I),I=1,10),(KONE1(I),I=1,10),(KONC1(I),I=MAIN0790
     2 1,10)                                                            MAIN0800
 9860  FORMAT(/1H03A6,I3,5H  DAY,I3,11H  ITERATION,I3,2X,1A6,/,
     1 10H MEN AVAIL ,F5.2,15H  START ALLOWED,F6.2,12H PRIOR EVENT,
     2 I4,9H FINISHED,F6.2,13H EVENT STARTS,F6.2,6H LASTS,F6.2,
     3 5H ENDS,F6.2,13H UNMANNED HRS,F7.2/                              MAIN0850
     4 13H GROUP STRESS,F5.2,9H PHYS CAP,F5.2,5H PACE,F4.1,5H  ASP,F5.2,MAIN0860
     5 8H PERF AD,F6.2,' HAZARD',F4.1,6X,'EVENT CLASS',I5,
     6                          /1X, 22HCONS, USED(UNITS/HR,) 10I6,
     9 /1X,22HCONS, LEFT(UNITS/HR,) 10I6,/1X,22HCONS, USED(UNITS)      , MAIN0880
     9 10I6,/1X,22HCONS, LEFT(UNITS)      10I6,/                        MAIN0890
     6 111HMAN TYPE  SPEC   LDR LEVEL FATIGUE PHYS CAP HRS WRKD CALORIESMAIN0900
     7 CALS+HRS SINCE SLEEP IDLE HRS SLEPT CUM PERF  ASP)               MAIN0910
 1868  CONTINUE                                                         MAIN0920
       DO 1870 I = 1,IG                                                 MAIN0930
       II = MAT(I)                                                      MAIN0940
       KK = ITYPE(II)                                                   MAIN0950
       TEM1 = PEA                                                       MAIN0960
        IF(KK.NE.IPS(II)) TEM1=ESSS                                     MAIN0970
       TEM2 = BLANK                                                     MAIN0980
       IF (II.EQ.LI) TEM2 = STAR                                        MAIN0990
       TEM3=IEC(KK)                                                     MAIN1000
       WRITE(6,9865) II,KK,TEM1,TEM2,ICF(II),FAT(II),PCC(II),TH(II),    MAIN1010
     1 CCAL(II),ACAL(II),HSLS(II),WH(II),DS(II),PERF(II),CASP(II)       MAIN1020
 9865  FORMAT (I3,I5,2A6,I6,F8.3,F9.3,F9.2,F9.1,F10.1,F11.1,F5.1,F10.1, MAIN1030
     1 F9.2,F5.2)                                                       MAIN1040
C                                                                       MAIN1050
 1870  CONTINUE                                                         MAIN1060
       GO TO 1890                                                       MAIN1070
C***     PRINT IGNORE DATA                                              MAIN1080
 1880  II = KK+2                                                        MAIN1090
       WRITE(6,9880) (TITLE(I),I=KK,II),LL,ND,ITER                      MAIN1100
 9880  FORMAT(/1H03A6,I3,5H  DAY,I3,11H  ITERATION,I3,                  MAIN1110
     1 18H IS IGNORED DUE TO)                                           MAIN1120
       IF(IGIND .GT. 1)  GO TO 1881                                     MAIN1130
```

```
      WRITE(6,9881) IESS
 9881 FORMAT(1H+,63X,20HLOW ESSENTIALITY OF I2)
      GO TO 1890
 1881 IF(IGIND .GT. 2)  GO TO 1882
      WRITE(6,9882)
 9882 FORMAT(1H+,63X,10HNULL GROUP)
      GO TO 1890
 1882 IF(IGIND .GT. 3)  GO TO 1883
      WRITE(6,9883)
 9883 FORMAT(1H+,63X,17HNO TIME AVAILABLE)
      GO TO 1890
 1883 IF (IGIND .GT. 4) GO TO 1884
      KK = TS (IE)
      WRITE(6,9884) (KONT(I,KK),I=1,10)
 9884 FORMAT(1H+,63X,38HCONSUMABLE (UNIT/HOUR) BELOW THRESHOLD/1H0,10F8,
     1 0)
      GO TO 1890
 1884 KK = TS1 (IE)
      WRITE (6,9885) (KONT1(I,KK),I=1,10)
 9885 FORMAT(1H+,63X,34HCONSUMABLE (UNITS) BELOW THRESHOLD/1H0,10F8.0)
C***    CHECK IF RETRY OF EVENT IS NECESSARY
 1890 IF(SUCC.EQ.ESSS) GO TO 1892
       IF(ITRY.GT.1) GO TO 1892
      IF(IGNOR .EQ. 1)  GO TO 1892
       IF(RTU(IE).EQ.3) GO TO 1892
      Z1=ZC(IE)
      Z2=Z1
       NREPT=NREPT+1
      IF(RTU(IE).NE.1) GO TO 1910
      RSSUC2=RSSUC2+PT(IE)
      WRITE(6,1812) RSSUC2,PT(IE)
      GO TO  1939
 1910 PT(IE)=0.5*PT(IE)+ASD     *RNORM1(0,0)
      RSSUC2=RSSUC2+PT(IE)
      WRITE(6,1812) RSSUC2,PT(IE)
 1812 FORMAT(1H ,'**** RSSUC2,PT(IE)=',2F10.2)
      GO TO 1939
C***    INCREMENT EVENT COUNTER AND TEST FOR END OF DAY
 1892 IEIE = INVS(IE)
      KK = NPTR(IEIE)
      IF(NPTR(IEIE) .EQ. 0)  GO TO 1920
      IF( NPTR(IEIE) .LE. 200)  GO TO 1900
C     KK = IE
      IE = NPTR(IEIE)
C***    IF EVENT IS NOT SCHEDULED WE MUST PRESERVE CHOICE OF FOLLOWING
C***         EVENT FROM NX AND PRB FOR CURRENT EVENT
C     DO 1895 I = 1,3
C     NX(I,IE) = NX(I,KK)
C1895 PRB(I,IE) = PRB(I,KK)
      GO TO 890
C***    DETERMINE NEXT EVENT USING NX AND PRB
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 1900 TEM1 = UNIFM1(0,0)
      KK = 1
      IF (TEM1.LT.PRB(1,IE)) GO TO 1910
      KK = 2
      IF (TEM1.LT.PRB(1,IE)+PRB(2,IE)) GO TO 1910
      KK = 3
 1910 CONTINUE
      IE = NX(KK,IE)
      IF(IE.EQ.0) GO TO 1920
      GO TO 850
C***     CALCULATE AVE PHYS WORKLOAD AND COMPETANCE FOR EACH CREW MEMBER
 1920 CONTINUE
      ETEM = 0.0
      TEMP = IC
      DO 1930 I = 1,IC
      ARW(I) = IDC(I)/CAL(I)*TW(I)/WORK1
      IF (TW(I) .GT. 0.001) GO TO 1921
      TEMP = TEMP - 1.0
      GO TO 1922
 1921 ETEM = ETEM + PERF(I)
 1922 IF (PCOM(I).GE.CASP(I)) GO TO 1930
      PCOM(I)=(CASP(I)-PCOM(I))*NU(I)*0.0017+PCOM(I)
 1930 CONTINUE
      ETEM = ETEM/TEMP
C***   PERFORMANCE EFFICIENCY
      TEM1=(1.0-(USHT/(WORK1*FLIC)))*(SEF/FLOAT(ISIE))
C     WRITE(6,1066) NIGNR,NSUC1,NSUC2,NFALE
C     WRITE(6,1063) TEM1
      REFF=TEM1*(1.0-(FLOAT(NIGNR)/FLOAT(NSUC1+NSUC2+NFALE)))
C
C     COMPUTE EQUIP AND HUMAN STATS  FOR HURT
      ATEM=0.
      BTEM=0.
      CTEM=0.
      DTEM=0.
      TEM1=IQMAX
      DO 1932  I=1,IQMAX
      IF (CDT (I) + CUT(I) .GT. 0.001) GO TO 1931
      TEM1 = TEM1 - 1.0
      GO TO 1932
 1931 CONTINUE
      ATEM=ATEM+ EPL(I)
      BTEM=BTEM + CART(I)
      CTEM=CTEM+ CDT(I)
      DTEM=DTEM+ CUT(I)
 1932 CONTINUE
      AEPL(ND)=ATEM/TEM1
      EPEFF=AEPL(ND)/CTEM*BTEM
      IF(EPEFF.LT.0.) EPEFF=0.
      IF(EPEFF.GT.1.) EPEFF=1.
      ENTDF=DTEM/(DTEM+CTEM)
```

```
      EMTTH=BTEM/FLOAT(NR)
C
       IF(ND.EQ.NDMAX) GO TO 1960
C***    CALCULATE PHYS INCAPACITIES
      NPI = IPUYSN(FLIC/NPI)
      IF (NPI.EQ.0) GO TO 1960
      DO 1950 I = 1,NPI
      II = UNIFM1(0,0)*FLIC
      PI(II) = 0.2*UNIFM1(0,0)+0.75
      KK = IPUYSN(PID)
       IF(KK.EQ.0) PI(II)=1.0
      IF (KK.GE.1) KK = KK-1
 1950 PI2(II) = KK
C***    CALCULATE SAFETY INDEX
 1960  CONTINUE
       TMW=0.0
       DO 1970 I=1,IC
 1970 TMW=TMW+TW(I)
      WR = TEM/(9.*TMW)
      CML = CML/(9.*TMW)
      SI = 9.78*(1.-WR)
 1980 CONTINUE
       TEM2=CN+.5
       DO 2260 JJ=1,IC
       WH(JJ)=24.0-Z(JJ)
       IF(WH(JJ).LT.TEM2) GO TO 2240
      IF(DS(JJ) .GE. MAXSL)  GO TO 2240
       TEM1=MAXSL-DS(JJ)
       DS(JJ)=AMIN1(DS(JJ)+WH(JJ)-.5,MAXSL)
       TEM1=AMIN1(WH(JJ),TEM1)-.5
      IF(TEM1 .LE. 9.0)  GO TO 2205
 2200 FAT(JJ) = 0.0
      GO TO 2220
 2205 IF(TEM1 .LT. 1.0)  GO TO 2210
      FAT(JJ) = FAT(JJ)*((138.0-19.0*TEM1)/140.0+0.2*UNIFM1(0,0))
      GO TO 2220
 2210 FAT(JJ) = FAT(JJ)*(0.9-0.05*TEM1+0.2*UNIFM1(0,0))
 2220 IF(FAT(JJ) .LT. 0.0)  FAT(JJ) = 0.0
      IF(FAT(JJ) .GT. 1.0)  FAT(JJ) = 1.0
      ADAL(JJ) = 0.0
      TEM1 = FAT(JJ)
      IF(TEM1 .GT. 0.9)  GO TO 2225
      IF(TEM1 .GT. 0.15)  GO TO 2224
      HSLS(JJ) = 53.333333 * FAT(JJ)
       GO TO 2260
 2224 HSLS(JJ) = 14.666667*TEM1+5.9
       GO TO 2260
 2225  HSLS(JJ)=AMAX1(310.0*TEM1-250.0,0.0)
       GO TO 2260
 2240 HSLS(JJ) = HSLS(JJ) + WH(JJ)
      FAT(JJ) = FNUILD(HSLS(JJ))
```

```
 2260 CONTINUE                                                            MAIN2680
       DO 2295 JJ=1,IC                                                    MAIN2690
      KK = IPS(JJ)                                                        MAIN2700
       TEM2=IEC(KK)   /PWR(JJ)                                            MAIN2710
      IF (TEM2.GE.1.0) GO TO 2285                                         MAIN2720
      EXER = 1.0                                                          MAIN2730
       GO TO 2290                                                         MAIN2740
 2285 EXER = (ZPC-TEM2)/(ZPC-1.0)                                         MAIN2750
      IF(EXER.LT.0.)WRITE(6,9900) ND,IE,PCC
 9900 FORMAT(1H ,'OVEREXERTION FACTOR EXCEEDED, DAY ',I3,', EVENT ',
    1 I4,' WORK RATE EXCEEDS PEAK WORK RATE ',F10.3)
 2290 TEM1=(ACAL(JJ)/CAL(JJ))**2                                          MAIN2760
      TEM1 = PC(JJ)*PI(JJ)*(1.0-(1.0-K1)*TEM1)*EXER*(1.0-0.1*FAT(JJ))     MAIN2770
      IF (TEM1.LT.0.0) TEM1    = 0.0                                      MAIN2780
      IF (TEM1.GT.2.0) TEM1    = 2.0                                      MAIN2790
 2295  PCC(JJ)=TEM1                                                       MAIN2800
      IF(NFALE .NE. 0)  SFDIFF=SFDIFF/FLOAT(NFALE)                        MAIN2810
       APA=APA/FLOAT(NSUC1+NSUC2+NFALE)                                   MAIN2820
      CALL OUTP2                                                          MAIN2830
      IF(ND.GE.NDMAX) GO TO 2030                                          MAIN2840
       ND=ND+1                                                            MAIN2850
       GO TO 650                                                          MAIN2860
 2030  CALL OUTP3                                                         MAIN2870
      IF((ITAP .EQ. 1) .AND. (N .GT. 1))  ENDFILE 10                      MAIN2880
       NDAYS=NDAYS+ND                                                     MAIN2890
       IF(ITER.LT.N) GO TO 50                                             MAIN2900
       CALL OUTP4                                                         MAIN2910
      GO TO 10                                                            MAIN2920
 3000  WRITE(6,3001) ITEM                                                 MAIN2930
 3001  FORMAT(26H1FATAL I/O ERROR FOR REC.=  I8)                          MAIN2940
      STOP                                                                MAIN2950
       END                                                                MAIN2960
CFBLD          FUNCTION FBUILD                                            FBLD0010
       FUNCTION FBUILD(H)                                                 FBLD0020
       HSLS=H                                                             FBLD0030
       TEM1=0.2*UNIFM1(0.0)                                               FBLD0040
       IF(HSLS.LT.8.0) GO TO 20                                           FBLD0050
       IF(HSLS.LT.19.0) GO TO 10                                          FBLD0060
       FBUILD=(HSLS+229.0)/310.0+TEM1                                     FBLD0070
       GO TO 5000                                                         FBLD0080
   10   FBUILD=(15.0*HSLS-109.0)/220.0+TEM1                               FBLD0090
       GO TO 5000                                                         FBLD0100
C////////////////////////////////                                         FBLD0110
   20 FBUILD = 0.01875 * HSLS - 0.1 + TEM1                                FBLD0120
 5000 IF(FBUILD .GE. 0.0)  GO TO 5002                                     FBLD0130
      FBUILD = 0.0                                                        FBLD0140
      GO TO 5555                                                          FBLD0150
 5002 IF(FBUILD .GT. 1.0)  FBUILD = 1.0                                   FBLD0160
 5555 RETURN                                                              FBLD0170
      END                                                                 FBLD0180
CIPUY          FUNCTION IPUYSH                                            IPUY0010
```

```
      FUNCTION IPUYSN(PAR)
      TEST=EXP(-PAR)
      K=0
      Y=UNIFM1(0,0)
 1000 IF(Y.LE.TEST) GO TO 5000
      K=K+1
      Y=Y*UNIFM1(0,0)
      GO TO 1000
 5000 IPUYSN=K
      RETURN
      END
CPSCAP      SUBROUTINE PSCAP
     SUBROUTINE PSCAP(IAA,PCDUM,PSCOM)
     DIMENSION IAA(4),PCDUM(6),PSCOM(40),TEM(3),L(3),LL(3),DATR(3)
     DATA DATR/0.95,0.75,0.60/
     NN=1
     DO 350 I=1,4,3
     DO 340 J=1,4
     L1=IAA(J)
     TEM1=L1
     KI=I
     DO 110 K=1,3
     TEM(K)=TEM1*PCDUM(KI)
     L(K)=TEM(K)
     KI=KI+1
 110 L1=L1-L(K)
     IF(L1.EQ.0)GO TO 275
     KI=I
     DO 130 K=1,3
      TEM(K)=TEM(K)-FLOAT(L(K))
      IF(TEM(K).LT.(.5)) GO TO 130
     L(K)=L(K)+1
     L1=L1-1
     IF(L1.EQ.0)GO TO 275
 130 CONTINUE
      DO 135 K=1,3
 135 LL(K)=K
     DO 150 K=1,2
     KK=3-K
     DO 140 II=1,KK
     IF(TEM(II).GE.TEM(II+1))GO TO 140
     TEMP=TEM(II)
     LT=LL(II)
     TEM(II)=TEM(II+1)
     TEM(II+1)=TEMP
     LL(II)=LL(II+1)
     LL(II+1)=LT
 140 CONTINUE
 150 CONTINUE
     DO 160 K=1,3
     KK=LL(K)
```

```
      L(KK)=L(KK)+1                                                   IPUY0540
      L1=L1-1                                                         IPUY0550
      IF(L1.EQ.0)GO TO 275                                            IPUY0560
  160 CONTINUE                                                        IPUY0570
      KK=LL(1)                                                        IPUY0580
      L(KK)=L(KK)+L1                                                  IPUY0590
  275 DO 310 K=1,3                                                    IPUY0600
      KK=L(K)                                                         IPUY0610
      IF(KK.EQ.0)GO TO 310                                            IPUY0620
      TEMP = DATR(K)                                                  IPUY0630
      DO 305 N=1,KK                                                   IPUY0640
       RSCOM(NN)=AMIN1(.99,TEMP+DNORM1(0,0)*0.03)                     IPUY0650
  305 NN=NN+1                                                         IPUY0660
  310 CONTINUE                                                        IPUY0670
  340 CONTINUE                                                        IPUY0680
  350 NN=21                                                           IPUY0690
      RETURN                                                          IPUY0700
      END                                                             IPUY0710
CINPUT          SUBROUTINE INPUT                                      INPT0010
      SUBROUTINE INPUT(ITER,KASE)                                     INPT0020
      COMMON/PRSNEL/WT,SIGHT,PPFD,PPHQ,PPUQ,SPFQ,SPHQ,SPUQ,           INPT0030
     1MPI,PID,ZPC,PTT(10,10),MEN(10,4),NDS,IDS(6,20)                  INPT0040
      COMMON/IPARAM/APST,WORK1,WORK2,SLEEP,CN,MAXSL,TFAT,ACP,         INPT0050
     1CALRY,PHRRT,K7,K1,BE,AASP,USHLIM,KON(10),KONT(10,10),KON1(10),
     2 KONT1(10,10),SESTA(10),RELI(4),N,IET,IND(7),NDMAX,IDFR(38,12)
      COMMON/EQREVNT/ IDF(30),RELH(30),DTR(570),TUI(30),IRE(30)       INPT0080
      COMMON/EEMER/ART(10),ASDE(10),DKE(10),IESSE(10) ,NREQE(10,10),  INPT0090
     1 LODME(10),IRCE(10,10),IRCE1(10,10),TSE(10),TSE1(10),IHE(10),   INPT0100
     1 IECE(10,10),DTBF(10),NDBE(10)                                  INPT0110
      COMMON/ETYPE/ADUR,ASD,IESS,NREQ(10),LODM,KE,INT,IRC(10),IRC1(10),INPT0120
     1 IH,IEC(10),NIQR,IQR(6),ICLASS                                  INPT0130
      COMMON/SEVENT/IETYP(570),TL(570),ST(570),EDCV(3,570),IPE(570),  INPT0140
     1 TS(570),TS1(570),NX(3,570),RTU(570),IFO1(570),IEFN(570),NIF(570),INPT0150
     2  IEDC(3,570),PRH(3,570),NOSE,NEQRE,NEME,DI(9)                  INPT0160
       DIMENSION FP1(111),IP1(161),FP2(249),IP2(9),FP3(2200),IP3(2200),INPT0170
     1 FP4(3660),IP4(3400),FP5(600),IP5(2000),DUMY(12),IDES(12)       INPT0180
      DIMENSION PITT(10,10)                                           INPT0190
      DIMENSION ADURIO(55),IPERCT(10)
      EQUIVALENCE(ADURIO,ADUR)                                        INPT0210
      EQUIVALENCE (WT,FP1),(MEN,IP1),(APST,FP2),(N   ,IP2),           INPT0220
     1 (FP3,FP4),(FP3,FP5),(IP3,IP4),(IP3,IP5),(IP3,IGBG),(FP3,GBG)   INPT0230
      INTEGER TS,TS1,RTU,TSE,TSE1,TSR,TSR1                            INPT0240
      REAL MPI,MAXSL,K7,K1,IEC,LODM,IH,IRC,KON,KON1,KONT,KONT1        INPT0250
       REAL IECE,IHE,IRCE,LODME                                       INPT0260
      NAMELIST/PERSNL/NFP1,FP1,NIP1,IP1                               INPT0270
      NAMELIST/PARAM/NFP2,FP2,NIP2,IP2                                INPT0280
      NAMELIST/SCHEVT/NFP3,FP3,NIP3,IP3                               INPT0290
      NAMELIST/EQREVT/NFP4,FP4,NIP4,IP4                               INPT0300
      NAMELIST/EMMEVT/NFP5,FP5,NIP5,IP5                               INPT0310
      NAMELIST/TYPE/ NFP5,FP5,NIP5,IP5                                INPT0320
      IERR = 0                                                        INPT0330
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      IF(ITER .GT. 1)  GO TO 225                                           INPT0340
  100 NFP2 = 0                                                             INPT0350
      NIP2 = 0                                                             INPT0360
      READ (5,PARAM)                                                       INPT0370
      IF((NFP2.NE.249).OR.(NIP2.NE.9)) GO TO 9010                          INPT0380
  101 WRITE(6,8100) NOMAX,IP2(1),(IDFR(1,I),I=1,12),
     1       FP2(8),FP2(1),FP2(14),FP2(9),      FP2(10)
      WRITE(6,8101) FP2(4),FP2(5),FP2(6),FP2(2),FP2(3),FP2(7),IP2(2),
     2 FP2(15),(FP2(I),I=11,13),(FP2(I),I=16,25),(FP2(I),I=126,135),
     3 (FP2(I),I=26,125),(FP2(I),I=136,249),(IP2(I),I=3,9)
 8100 FORMAT(1H1,'PARAMETER INPUTS FOR THIS',I3,' DAY RUN OF',I3,
     1 '   MISSION ITERATIONS',/,5X,'ENTITLED ',12A6,//,
     2 '- - - - AVERAGE CREW DATA - - - -',/,1X,'PACE    STRESS    ASPIR-
     3 CALORIES REQD  POWER RATE',/
     3                             7X,'THRESHOLD  ATION',6X,'PER DAY',6X,
     4'CALS/HR,',/,F5.2,F6.2,F10.2,F13.0,F13.1,
     4///,                                       'HOURS SINCE  CATNAP  MAXI
     5MUM  --WORK LIMITS(HRS)--  -------THRESHOLDS------  -------------CO
     6NSTANTS---------------------')
 8101 FORMAT(1H ,                  'LAST SLEEP   LENGTH   SLEEP      NO MORE
     7NO MORE  FATIGUE  ESSENTIALITY    UNMANNED    LEADERS     PHYSICAL
     8     STRESS'/,14X,'(HRS)  PER DAY  ASSIGNMENTS   WORK',27X,'STATION
     9 HRS  EXPECTATION  CAPABILITY',/,F7.1,F11.1,F8.1,2F11.1,F9.2,I13,
     93F13.2,F9.2,///,81X,'NUMBER',/,44X,            '1',7X,'2',
     A 7X,'3',7X,'4',7X,'5',7X,'6',7X,'7',7X,'8',7X,'9',6X,'10',/,
     B 'INITIAL VALUE OF CONSUMABLES (UNITS)   ',10F8.0,/,
     C 'INITIAL VALUE OF CONSUMABLES (UNITS/HR)',F7.0,9F8.0//,32X,'SET',
     D /,'CONSUMABLE THRESHOLDS (UNITS)',4X,'1',4X,10F8.0,/,33X,'2',4X,
     E 10F8.0,/,33X,'3',4X,10F8.0,/,33X,'4',4X,10F8.0,/,33X,'5',4X,
     F 10F8.0,/,33X,'6',4X,10F8.0,/,33X,'7',4X,10F8.0,/,33X,'8',4X,
     G10F8.0/33X,'9',4X,10F8.0,/32X,'10',4X,10F8.0//'CONSUMABLE THRESHOL
     HDS (UNITS/HR) 1',4X,10F8.0,/,33X,'2',4X,10F8.0,/,33X,'3',4X,
     J 10F8.0,/,33X,'4',4X,10F8.0,/,33X,'5',4X,10F8.0,/,33X,'6',4X,
     K 10F8.0,/,33X,'7',4X,10F8.0,/,33X,'8',4X,10F8.0,/,33X,'9',4X,
     L 10F8.0,/,32X,'10',4X,10F8.0,//,'CUMMULATIVE PROBABILITY OF SEA ST
     MATES   ',10F8.2,  ,/,'AVERAGE EQUIPMENT INTERMITTANT RELIABILITY',
     NF6.2,3F8.2/,'OUTPUT RECORDING OPTIONS',13X,7I8)
  200 IF(KASE .LE. 1)  GO TO 201                                           INPT0480
      DO 205 I=1,10                                                        INPT0490
      DO 205 J=1,10                                                        INPT0500
      PTT(I,J) = PTTT(I,J)                                                 INPT0510
  205 CONTINUE                                                             INPT0520
  201 NFP1 = 0                                                             INPT0530
      NIP1 = 0                                                             INPT0540
      READ (5,PERSNL)                                                      INPT0550
      IF ((NFP1.NE.111).OR.(NIP1.NE.161)) GO TO 9020                       INPT0560
      IF(KASE .NE. 1)  GO TO 209                                           INPT0570
      DO 208 I=1,10                                                        INPT0580
      DO 208 J=1,10                                                        INPT0590
      PTTT(I,J) = PTT(I,J)                                                 INPT0600
  208 CONTINUE                                                             INPT0610
```

```
  209 DO 220 I=1,10                                                        INPT0620
      DO 210 J=2,10                                                        INPT0630
      PTT(J,I)=PTT(J,I)+PTT(J-1,I)                                         INPT0640
  210 CONTINUE                                                             INPT0650
  220 CONTINUE                                                             INPT0660
  225 IF(IND(1) .EQ. 0 .OR. ITER .GT. 1) GO TO 299                         INPT0670
      WRITE(6,8200) (FP1(I),I=1,5),(IP1(I),I=1,10),(FP1(I),I=6,8),
     1(IP1(I),I=11,40),(FP1(I),I=12,21),(IP1(6*I),I=7,26),
     2(FP1(I),I=22,31),(IP1(6*I+1),I=7,26),(FP1(I),I=32,41),
     3(IP1(6*I+2),I=7,26),(FP1(I),I=42,51),(IP1(6*I+3),I=7,26),
     4(FP1(I),I=52,61),(IP1(6*I+4),I=7,26),(FP1(I),I=62,71),
     5(IP1(6*I+5),I=7,26),(FP1(I),I=72,111)
 8200 FORMAT(1H1,58X,'PERSONNEL DATA',//,' - BODY WEIGHT -   SPECIALTY
     1FRACTION OF CREW QUALIFIED   LEVEL    NUMBER OF MEN IN CREW BY TYP
     2E',/,'  MEAN    SIGMA',17X,'FULLY   MINIMALLY   UN',15X,'1  2  3  4
     3  5  6  7  8  9 10',//,F6.1,F8.1,6X,'PRIMARY',4X,F6.2,2X,
     1 2F8.2,6X,'1',5X,10I3,/,20X,'SECONDARY',2X,F6.2,2X,
     4 2F8.2,6X,'2',5X,10I3,/,61X,'3',5X,10I3,/,61X,'4',5X,10I3,//,
     5 ' MAN   CUMULATIVE CROSS TRAINING PROBABILITIES',28X,
     6 'CREW ASSIGNMENT TO SHIFTS BY MAN',/,'TYPE',5X,
     7 '1    2    3    4    5    6    7    8    9   10     SHIFT   1  2
     8 3   4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20',//,'  1',5X,
     9 10(F4.2,1X),'    1   ',20I3,/,'  2',5X,10(F4.2,1X),'    2   ',20I3,
     A /,'  3',5X,10(F4.2,1X),'    3   ',20I3,/,'  4',5X,10(F4.2,1X),
     B '    4   ',20I3,/,'  5',5X,10(F4.2,1X),'    5   ',20I3,/,'  6',5X,
     C 10(F4.2,1X),'    6   ',20I3,/,'  7',5X,10(F4.2,1X),/,'  8',5X,
     D 10(F4.2,1X),10X,'(1 - ASSIGNED    0 - UNASSIGNED)',/,'  9',5X,
     E 10(F4.2,1X),/,' 10',5X,10(F4.2,1X))
      WRITE(6,8300) MPI,PID,ZPC
 8300 FORMAT (1H //////,'--PHYSICAL CAPABILITY AVERAGES--',10X,
     1 'PHYSICAL',/,'MAN DAYS PER', 9X,'DURATION',12X,'CAPABILITY',/,
     2 ' INCIDENCE',33X,'CONSTANT',//,F7.2,16X,F3.1,18X,F4.2)
  299 IF(ITER.EQ.1) GO TO 300                                              INPT0840
      REWIND 10                                                            INPT0850
      READ(10) NFP4,NIP4,NEQRE,(FP4(I),I=1,NFP4),(IP4(I),I=1,NIP4)         INPT0860
      GO TO 301                                                            INPT0870
  300 NFP4 = 0                                                             INPT0880
      NIP4 = 0                                                             INPT0890
      READ (5,EQREVT)                                                      INPT0900
      NEQRE=IP4(1)                                                         INPT0910
      IF(N .LE. 1)  GO TO 301                                              INPT0920
      REWIND 10                                                            INPT0930
      WRITE(10) NFP4,NIP4,NEQRE,(FP4(I),I=1,NFP4),(IP4(I),I=1,NIP4)        INPT0940
  301 KK = 2                                                               INPT0950
      MM = 1                                                               INPT0960
      IF (IND(1) .NE. 0 .AND. ITER .LE. 1) WRITE (6,8329)                  INPT0970
      DO 350 I = 1,NEQRE                                                   INPT0980
 8329 FORMAT(1H1,49X,'EQUIPMENT AND REPAIR EVENT DATA')                    INPT0990
      DO 305 J=1,12                                                        INPT1000
      IDES(J)=IP4(KK)                                                      INPT1010
      IDFR(I,J)=IP4(KK)
```

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  305 KK=KK+1
      TSR = IP4 (KK)
      TSR1 = IP4 (KK + 1)
      IREX=IP4(KK+2)
      IRE(I)=IREX
      IEFNX=IP4(KK+3)
      KK=KK+3
      RELH(I)=FP4(MM)
      TUI(I)=FP4(MM+1)
C     DTR(I)=FP4(MM+2)
      MM=MM+2
      J=200+(I-1)*12
      ITEM=J
      DO 310  JJ=1,IREX
      TS(J)=TSR
      J=J+1
      TS1(J)=TSR1
      IETYP(J) = IP4 (KK + 1)
      IRE(J) = IP4 (KK + 2)
      IF(IPE(J).NE.0) IPE(J)=IPE(J)+ITEM
      NX (1,J) =  IP4 (KK + 3)
      NX (2,J) =  IP4 (KK + 4)
      NX(3,J) =   IP4 (KK + 5)
      NX(1,J)=NX(1,J)+ITEM
      NX(2,J)=NX(2,J)+ITEM
      NX(3,J)=NX(3,J)+ITEM
      RTU(J) =    IP4 (KK + 6)
      IFOI(J) =   IP4 (KK + 7)
      IEFN(J)=IEFNX
      DTR(J)=FP4(MM)
      PRB(1,J) = FP4 (MM + 1)
      PRB(2,J) = FP4 (MM + 2)
      PRB(3,J)= FP4 (MM + 3)
      IEDC(1,J)=FP4(MM+4)
      IEDC(2,J)=FP4(MM+5)
      IEDC(3,J)=FP4(MM+6)
      EDCV(1,J)=FP4(MM+7)
      EDCV(2,J)=FP4(MM+8)
      EDCV(3,J)=FP4(MM+9)
      ST(J) = 0.0
      TL(J) = 24.0
       KK=KK+7
      MM=MM+10
  310 CONTINUE
      JJ=J
      KK = KK + 1
C     MM = MM + 1
      II=J-IREX+1
      IF (IND(1) .NE. 0 .AND. ITFR .LE. 1) WRITE(6,8330)
     1 I,IDES,TSR,TSR1,RELH(I),TUI(I),  IREX,(IETYP(J),(NX(K,J),K=1,3),
     2 (PRB(K,J),K=1,3),RTU(J),(IEDC(K,J),K=1,3),
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```
     3 (EDCV(K,J),K=1,3),IPE(J),IFOI(J),IEFN(J),DTR(J),(J-200-(I-1)*12),
     4 J,J=II,JJ)
 8330 FORMAT(1H0//'EQUIP  DESCRIPTION'57X,'-CONSUM. THRESHOLD SET-   REL
     1IABILITY    TIME     EVENTS/'/1X,'TYPE',72X,'(UNITS/HR)   (UNITS)',
     2 5X,'(DAYS/FAIL)   UNAVAIL  FAMILY'/,I4,3X,12A6,I4,I11,8X,F8.3,6X,
     3 F5.2,5X,I2,//,
     4 'EVENT   NEXT EVENT    PROBABILITY   REPEAT/  DATA CHG NO  DATA C
     5HANGE VALUE  PREC.  FAMILY  FAMILY  DURATION      EVENT NUMBER',/,
     6 ' TYPE      1    2    3    1    2    3   TOUCHUP    1   2   3   1
     6  2     3    EVENT  INDIC.  NUMBER   TARGET   IN FAMILY  COMPUTER'
     7 ,/,(1H ,I3,3X,3I4,3F5.2,I6,4X,3I4,3F6.0,2I7,I9,F10.2,I9,I10))
  350 CONTINUE                                                          INPT1630
  399  IF(ITER.EQ.1) GO TO 400                                          INPT1640
       NFP5=NEME*3                                                      INPT1650
      NIP5=NEME*47                                                      INPT1660
       READ(10) (FP5(I),I=1,NFP5),(IP5(I),I=1,NIP5)                     INPT1670
       GO TO 401                                                        INPT1680
  400 NFP5 = 0                                                          INPT1690
      NIP5 = 0                                                          INPT1700
      READ (5,EMREVT)                                                   INPT1710
      NEME = NFP5/3                                                     INPT1720
      NFP3=NIP5/58                                                      INPT1730
      IF((NFP5.NE.NEME*3).OR.(NIP5.NE.NFP3*58)) GO TO 9040              INPT1740
       IF(N.GT.1) WRITE(10) (FP5(I),I=1,NFP5),(IP5(I),I=1,NIP5)         INPT1750
  401 KK = 1                                                            INPT1760
      MM = 1                                                            INPT1770
      IF (IND(1) .NE. 0 .AND. ITER .LE. 1) WRITE(6,8429)                INPT1750
 8429 FORMAT(1H1,49X,'EMERGENCY EVENT DATA')
      DO 450 I = 1,NEME                                                 INPT1840
      ART(I) = FP5(KK)                                                  INPT1850
      ASDE(I) = FP5(KK + 1)                                             INPT1860
      DTE(I) = FP5(KK + 2)                                              INPT1870
      DO 405 J=1,12                                                     INPT1880
      IDES(J)=IP5(MM)                                                   INPT1890
  405  MM=MM+1                                                          INPT1900
      IESSE(I)=IP5(MM)                                                  INPT1910
      DO 410 J =1,10                                                    INPT1920
      MM = MM + 1                                                       INPT1930
  410 NREGE (J,I) = IP5(MM)                                             INPT1940
      MM=MM+1                                                           INPT1950
      LODME( I)=IP5(MM)                                                 INPT1960
      DO 420 J=1,10                                                     INPT1970
      MM = MM + 1                                                       INPT1980
  420 IRCE (J,I) = IP5(MM)                                              INPT1990
      MM = MM + 1                                                       INPT2000
      TSE(I) = IP5 (MM)                                                 INPT2010
      DO 425 J=1,10                                                     INPT2020
      MM = MM + 1                                                       INPT2030
  425 IRCE1(J,I) = IP5 (MM)                                             INPT2040
      TSE1(I) = IP5(MM + 1 )                                            INPT2050
      THE(I) = IP5 (MM + 2)                                             INPT2060
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      MM = MM + 3                                                       INPT2070
      DO 430 J =1,10                                                    INPT2080
      IECE(J,I) = IP5 (MM)                                              INPT2090
  430 MM = MM + 1                                                       INPT2100
      DO 435 J=1,10
      IPERCT(J)=IECE(J,I)
  435 CONTINUE
      NDBE(I) = IP5 (MM)                                                INPT2110
      MM = MM + 1                                                       INPT2120
      KK = KK + 3                                                       INPT2130
      IBTYP(I+560)=-1                                                   INPT2140
      SY(I+560)= 0.                                                     INPT2150
      TL(I+560) = 24.0                                                  INPT2160
      TB(I+560)= TSE(I)                                                 INPT2170
      TS1(I+560)= TSE1(I)                                               INPT2180
      RTU(I+560)=1                                                      INPT2190
      IFOI(I+560)=1                                                     INPT2200
      IEFN(I+560)=0                                                     INPT2210
      NIF(I+560)=1                                                      INPT2220
      IBDC(1,I+560)=0,                                                  INPT2230
      IBDC(2,I+560)=0,                                                  INPT2240
      IBDC(3,I+560)=0,                                                  INPT2250
      IF ( IND(1) .NE. 0 .AND. ITER .LE. 1)                             INPT2260
     1WRITE(6,6449) I,IDES,ART(I),ASME(I),TSE(I),TSE1(I),IESSE(I),
     1 LODME(I),IME(I),(NREQE(J,I),J=1,10),(IRCE(J,I),J=1,10),NDBE(I),
     2 DTE(I),(IPERCT(J),J=1,10),(IRCE1(J,I),J=1,10)
 6449 FORMAT(///'EMER   DESCRIPTION',T82,'--REPAIR TIME--      CONSUM THR
     1ESHOLD     SET',/,' NO,',T86,'AVG    SIGMA',8X,'(UNITS/HR)',6X,
     2 'UNITS',//,I3,4X,
     2 12A6,T85,F4.2,T94,F4.2,T107,I2,T121,I2,//,' ESSEN-  MENTAL  HAZAR
     3D        NUMBER OF MEN REQUIRED',T72,'CONSUMABLE EXPENDITURE RATE(UN
     4ITS/HR)     DAYS/    DURATION',/,'TIALITY   LOAD',T28,
     5 'EXPECTED ENERGY CONSUMPTION (CAL/HR.)',
     5                                    T72,'CONSUMABLE EXPENDITURE RATE(UN
     6ITS)',T111,'EMERGENCY   TARGET',/,T29,'1   2   3   4   5   6   7
     7 8   9  10',T72,' 1  2  3  4  5  6  7  8  9 10',//,I5,2(6X,F2.0),
     8 9X,10I4,T72,10(F3.0),T115,I2,8X,F4.2,/,T27,10I4,T71,10I3)
  450 CONTINUE                                                          INPT2340
  601  IF(ITER.GT.1) GO TO 651                                          INPT2350
       NFP5=0                                                           INPT2360
      NIP5=0                                                            INPT2370
      READ(5,TYPE)                                                      INPT2380
      IF(IND(1).NE.0 .AND.ITER.LE.1) WRITE(6,9601)                      INPT2390
 9601 FORMAT(1H1/50X,'EVENT TYPE DATA',///,
     1'I',128('-'),'I',/,'I',117X,'EQUIPMENT  I',/,
     2 'I TYPE  IDENTIFIER',64X,'DURATION      CLASS   NUMBER OF      NUMB
     3ERS REQD', 'I',/,'I',79X,'AVG.  SIGMA',11X,'EQUIPS. REQD.   1 2 3
     44 5 6I',  /,'I',128X,'I',/,'I',128('-'),'I',/,'I',128X,'I',/,
     5 'I ESSEN-  MENTAL  EVENT  TRAIN HAZARD',9X,'NUMBER OF MEN REQUIRE
     6D',16X,'CONSUMABLE EXPENDITURE RATE (UNITS/HR.)',6X,'I',/,'I TIALI
     7TY  LOAD    KIND   CODE',99X,'I',/,'I',128X,'I',/,'I',128('-'),
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      8 '!',/,'!',128X,'!',/,'!',40X,'CONSUMABLE EXPENDITURE RATE (UNITS)
      9',14X,'EXPECTED ENERGY CONSUMPTION',12X,'!',/,'!',40X,'1    2    3
      A 4    5    6    7    8    9   10    1    2    3    4    5    6    7
      B8     9    10!',/,'!',128X,'!',/,'!',128('='),'!',///)
       NTYPES=NIP5/65
       MM = 1
       KK = 1
       DO 650 I=1,NTYPES
       DO 605 J=1,12
       IDES(J)=IP5(MM)
  605  MM=MM+1
       IESS=IP5(MM)
       MM=MM+1
       ADUR = FP5 (KK)
       ASD = FP5 (KK + 1)
       DO 610 J=1,10
       NREQ(J) = IP5 (MM)
  610  MM = MM + 1
       LODM = IP5 (MM)
       KE = IP5 ( MM + 1)
       INT = IP5 (MM + 2)
       MM = MM + 3
       DO 615 J=1,10
       IRC (J) = IP5 ( MM)
       IRC1(J) = IP5 (MM + 10)
  615  MM = MM + 1
       IH=IP5(MM+10)
       MM=MM+11
       DO 620 J=1,10
       IEC (J) = IP5 (MM)
  620  MM = MM + 1
       NIQR = IP5 ( MM)
       DO 625 J=1,6
       MM = MM + 1
  625  IQR(J) = IP5 (MM)
       ICLASS = IP5 (MM + 1)
       WRITE(12'I,ERR=9060) ADURIO
       IF(IND(1).NE.0 .AND. ITER.LE.1)
      1 WRITE(6,9650) I,IDES,ADUR,ASD,ICLASS,NIQR,(IQR(J),J=1,6),IESS,
      1 LODM,KE,INT,IH, (NREQ(J),J=1,10), (IRC(J),J=1,10),(IRC1(J),J=1,10
      2), (IEC(J),J=1,10)
 9650  FORMAT(/I4,3X,12A6,2F7.3,I6,7X,I4,7X,6I2/,I5,F8.0,I8,I6,F7.0,4X,
      1 10I4,2X,10F5.0/38X,10I4,2X,10F5.0)
       KK = KK + 2
  650  MM = MM + 2
  651  RETURN
       ENTRY DINPUT
        IF(ITER.EQ.1) GO TO 500
        READ(10) ND,NOSE,(DUMY(I),I=1,11)
  475   NFP3=NOSE*11
        NIP3=NOSE*11
```

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      READ(10) (FP3(I),I=1,NFP3),(IP3(I),I=1,NIP3)                    INPT2930
      GO TO 501                                                       INPT2940
  500 NFP3 = 0                                                        INPT2950
      NIP3 = 0                                                        INPT2960
      READ (5,8500)ND,NOSE,(DUMY(I),I = 1,11)                         INPT2970
 8500 FORMAT (2I3,11A6)                                               INPT2980
      READ (5,SCHEVT)                                                 INPT2990
      IF((NFP3.NE.NOSE*11).OR.(NIP3.NE.NOSE*11)) GO TO 9050           INPT3000
      IF(N.LE.1) GO TO 501                                            INPT3010
      WRITE(10) ND,NOSE,(DUMY(I),I=1,11)                              INPT3020
      WRITE(10) (FP3(I),I=1,NFP3),(IP3(I),I=1,NIP3)                   INPT3030
  501 KK = 1                                                          INPT3040
      MM = 1                                                          INPT3050
      DO 560 I = 1,NOSE                                               INPT3060
      IETYP(I)=IP3(KK)                                                INPT3070
      IPE(I)=IP3(KK+1)                                                INPT3080
      TS(I)=IP3(KK+2)                                                 INPT3090
      TS1(I)=IP3(KK+3)                                                INPT3100
      RTU(I)=IP3(KK+4)                                                INPT3110
      IFOI(I)=IP3(KK+5)                                               INPT3120
      NIF(I)=IP3(KK+6)                                                INPT3130
      IEFN(I)=IP3(KK+7   )                                            INPT3140
      KK=KK+8                                                         INPT3150
      TL(I)=FP3(MM)                                                   INPT3160
      ST(I)=FP3(MM+1)                                                 INPT3170
      MM=MM+2                                                         INPT3180
      DO 510 J = 1,3                                                  INPT3190
      NX(J,I)=IP3(KK)                                                 INPT3200
      PRB(J,I)=FP3(MM)                                                INPT3210
      MM=MM + 1                                                       INPT3220
  510 KK = KK+1                                                       INPT3230
      DO 520 J=1,3                                                    INPT3240
      TDC(J,I)=FP3(MM)                                                INPT3250
      EDCV(J,I)=FP3(MM+3)                                             INPT3260
  520 MM = MM + 1                                                     INPT3270
      MM = MM + 3                                                     INPT3280
  560 CONTINUE                                                        INPT3290
      IF(IND(1) .EQ. 0  .OR.  ITER .GT. 1)  GO TO 4999                INPT3300
      WRITE(6,8501) NOSE,ND,(DUMY(I),I=1,11)
 8501 FORMAT(1H1,45X,'SCHEDULED EVENT SEQUENCE DATA',//,'FOR',I4,
     1 ' SCHEDULED EVENTS OF DAY',I3,' ENTITLED# ',11A6,7X,'RTU CODE',/,
     2 116X,'1-REPEAT',/,'EVENT    TYPE    THRESHOLD SET       NEXT EVENT AN
     3D PROBABILITY      PRECEDENT    START    TIME    REPEAT/TOUCHUP',
     4 13X,'2-TOUCHUP',/,' NO.',11X,'UNITS/HR UNITS',6X,'1', 9X,'2',10X,
     5 '3',7X,'EVENT NO.',3X,'TIME',4X,'LIMIT',7X,'CODE',18X,
     6 '3-NEXT EVENT')
      WRITE(6,8560) (I,IETYP(I),TS(I),TS1(I),NX(1,I),PRB(1,I),NX(2,I),
     1 PRB(2,I),NX(3,I),PRB(3,I),IPE(I),ST(I),TL(I),RTU(I),I=1,1)
      DO 8600 I=2,NOSE
      WRITE(6,8560) I,IETYP(I),TS(I),TS1(I),NX(1,I),PRB(1,I),NX(2,I),
     1 PRB(2,I),NX(3,I),PRB(3,I),IPE(I),ST(I),TL(I),RTU(I)
```

```
      IF(MOD(I,24).EQ.0) WRITE(6,8501) NOSE,ND,(DUMY(J),J=1,11)
 8400 CONTINUE
 8500 FORMAT(1H0,  1H ,I3,I8,I6,I8,2X,3(I5,F6.2),I10,F10.2,F7.2,I14)
 4999 CONTINUE                                                          INPT3440
 5000 IF (IERR.EQ.0) RETURN                                             INPT3450
      STOP                                                              INPT3460
 9010 IERR = 1                                                          INPT3470
      WRITE (6,9011)                                                    INPT3480
 9011 FORMAT (30H1ERROR IN FOLLOWING INPUT LIST/25HPROGRAM WILL NOT CONTINPT3490
     1INUE)                                                             INPT3500
      WRITE (6,PARAM)                                                   INPT3510
      GO TO 200                                                         INPT3520
 9020 IERR = 1                                                          INPT3530
      WRITE (6,9011)                                                    INPT3540
      WRITE (6,PERSNL)                                                  INPT3550
      GO TO 300                                                         INPT3560
C9030 IERR = 1                                                          INPT3570
C     WRITE (6,9011)                                                    INPT3580
C     WRITE (6,EQMEVT)                                                  INPT3590
C     GO TO 400                                                         INPT3600
 9040 IERR = 1                                                          INPT3610
      WRITE (6,9011)                                                    INPT3620
      WRITE (6,EMMEVT)                                                  INPT3630
      GO TO 601                                                         INPT3640
 9050 IERR = 1                                                          INPT3650
      WRITE (6,9011)                                                    INPT3660
      WRITE(6,SCHEVT)                                                   INPT3670
      GO TO 5000                                                        INPT3680
 9060 WRITE(6,9012)                                                     INPT3690
 9012 FORMAT(20H1D, A, ERROR--QUIT                                      INPT3700
      RETURN                                                            INPT3710
      END                                                               INPT3720
COUTP1      SUBROUTINE OUTP1                                            OUTP0010
      SUBROUTINE OUTP1                                                  OUTP0020
      INTEGER PI2                                                       OUTP0030
      COMMON/QCOM/PCOM(20),SCOM(20),IPS(20),ISS(20),TPCOM(20),TSCOM(20) OUTP0040
      COMMON/SEVENT/IETYP(570),TL(570),ST(570),EDCV(3,570),IPE(570),    OUTP0050
     1 TS(570),TS1(570),NX(3,570),RTU(570),IFOI(570),IEFN(570),NIF(570),OUTP0060
     2 IEDC(3,570),PRR(3,570),NOSE,NEQRE,NEME,DT(9)                     OUTP0070
      COMMON/OPP1/ IAA(4),PC(20),PACE(20),ASP(20),HSLS(20),PI(20)       OUTP0080
     1,PI2(20),ICE(20)                                                  OUTP0090
      COMMON/OPP2/ TW(20),TWP(20),TWS(20),DS(20),APW(20),PCC(20),       OUTP0100
     1              CASP(20),IDC(20),       NSUC1,NSUC2,NFALE,NIGNR,    OUTP0110
     2 MONC(10),KONC1(10), SI,CML,ND,ITER,NDAYS,MPCC(20),FAT(20)        OUTP0120
     3 ,STRR(20),CAL(20),PWR(20),CCAL(20),NU(20),PERF(20),NPRFR(4)      OUTP0130
     4 ,APA,SFDIFF,CLSDTA(10,40)                                        OUTP0140
      COMMON/OPP3/IC,FLIC,NREPT,HRSE,HRSR,HRSS,PEFF,                    OUTP0150
     1 MAXST,MAXSTF,USHT,NR,NTE,PE,TFH,CHLMX,ICHL,SIDCHX,INCMX,ICSS     OUTP0160
      COMMON/OPP4/EPL(30),CDT(30),CART(30),CUT(30),                     OUTP0170
     1        EPEFF,ENTRF,EMTTR,SRL,SPL,SGEM,RSSUC2,SCDTIQ,REPTM,
     1          ACART(10),ACDT(10),ACUT(10), AEPL(10),DEPEFF(10)
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C     1 AEPL,EPEFF,EMTBF,EMTTR,SRL,SPL,SGEM
      REAL MAXST,IITER ,JITER
      COMMON/IPARAM/APST,WORK1,WORK2,SLEEP,CN,MAXSL,TFAT,ACP,
     1CALRY,PWRRT,K7,K1,BE,AASP,USHLIM,KON(10),KONT(10,10),KON1(10),
     2 KONT1(10,10),SESTA(10),RELI(4),N,IET,IND(7),NDMAX,IDFR(38,12)
      REAL IDC, KON, KONC, MPCC, MU, IMTAB(13,21,10),KON1
       DIMENSION OUTA(35),TEM3(20),DALY(35,30),IITER(35,10),T3(10)
       DIMENSION TOUTA(13,10),NTIPE(10),TDALY(13,10,30),TIITER(13,10,10)
     1 ,ADALY(10,30), IDALY1(10,30),JITER(20,10),OUTB(20),IKONC(10)
      DIMENSION CLSNME(37),CLSDTI(10,40),CLSDTR(10,40),IPERCT(10)
       DATA CLSNME/ 1HC ,1HO,1HD      ,1HA      ,2HEY     ,4HEURM  ,2HEC
     1 ,3HECA    ,2HER     ,2HEO     ,3HEIP    ,2HEI     ,4HERPY  ,5HELURM ,
     2 3HELC    ,3HELA    ,3HELR    ,3HELO    ,4HELEP   ,3HELI   ,5HELRPT ,
     3 5HEMURM  ,3HEMC    ,3HEMA    ,3HEMR    ,3HEMO    ,4HEMEI  ,3HEMI   ,
     4 5HEMRPT  ,4HMURM   ,2HMC     ,2HMA     ,2HMR     ,2HMO    ,3HMEI   ,
     5 2HMI     ,4HMRPT   /
       DATA CI/6H      /
       DO 380 I=1,10
  380  NTIPE(I)=0
       DO 390 I=1,IC
       K=IPS(I)
  390  NTIPE(K)=NTIPE(K)+1
      IF(IND(2) .EQ. 0)  RETURN
       WRITE(6,9414)
 9414 FORMAT(1H1,'START OF MISSION CREW DATA BY TYPE',//,
     1                                         'TYPE  PHYS.     COMPET
     1ANCE        PACE    ASPIR-    HRS SINCE    PHYSICAL'/4X,'CAPABIL  PRIM
     2ARY SECONDARY',10X,'ATION   LAST SLEEP  INCAPACITY')
       K = 0
       DO 420 I = 1,4
       KK = IAA(I)
       IF (KK.EQ.0) GO TO 420
       K = K+1
       PCA = PC(K)
       PCOMA = PCOM(K)
       SCOMA = SCOM(K)
       PACEA = PACE(K)
       ASPA = ASP(K)
       HSLSA = HSLS(K)
       PIA = PI(K)
       IF (KK.EQ.1) GO TO 415
       DO 410 J = 2,KK
       K = K+1
       PCA = PCA+PC(K)
       PCOMA = PCOMA+PCOM(K)
       SCOMA = SCOMA+SCOM(K)
       PACEA = PACEA+PACE(K)
       ASPA = ASPA+ASP(K)
       HSLSA = HSLSA+HSLS(K)
  410  PIA = PIA+PI(K)
       TEM1 = KK
```

```
      PCA = PCA/TEM1                                                    OUTP0680
      PCOMA = PCOMA/TEM1                                                OUTP0690
      SCOMA = SCOMA/TEM1                                                OUTP0700
      PACEA = PACEA/TEM1                                                OUTP0710
      ASPA = ASPA/TEM1                                                  OUTP0720
      HSLSA = HSLSA/TEM1                                                OUTP0730
      PIA = PIA/TEM1                                                    OUTP0740
  415 WRITE (6,9415)I,PCA,PCOMA,SCOMA,PACEA,ASPA,HSLSA,PIA              OUTP0750
 9415 FORMAT(I3,    F8.3,F9.3,F10.3,F7.3,F8.3,F11.3,F12.3)
  420 CONTINUE                                                          OUTP0770
      WRITE(6,9416) (I,PC(I),PCOM(I),SCOM(I),PACE(I),ASP(I),HSLS(I),    OUTP0780
     1 PI(I),PI2(I),FAT(I),STRM(I),CAL(I),PWR(I),ICE(I),IPS(I),ISS(I),  OUTP0790
     2 I=1,IC)                                                          OUTP0800
 9416 FORMAT(1H ,////,'START OF MISSION CREW DATA BY MAN',//,
     1              'MAN  PHYS-      COMPETANCE     PACE  ASPIR-  HRS
     1 SINCE  PHYSIC   INCAP  FAT-    STRESS   CALOR-  POWER    LEVEL
     2SPECIALTY',/,
     3           'NO, CAPABIL  PRIMARY SECONDARY',9X,'ATION  LAST SLEEP DUR
     4ATION EXTENT IGUE  THRESHOLD   IES     RATE',
     4 'PRIMARY SECONDARY',/,(I3,
     4 2X,F5.3,F9.3,F10.3,F7.3,F8.3,F12.3,F8.3,I5,F8.3,F10.3,F9.0,F7.1,
     5 I7,2X,2I6))
      DO 425 I=1,12                                                     OUTP0840
  425 OUTA(I) = 0.0                                                     OUTP0850
      DO 430 I=1,IC                                                     OUTP0860
      OUTA(1) = OUTA(1)+PC(I)                                           OUTP0870
      OUTA(2) = OUTA(2)+PCOM(I)                                         OUTP0880
      OUTA(3) = OUTA(3)+SCOM(I)                                         OUTP0890
      OUTA(4) = OUTA(4)+PACE(I)                                         OUTP0900
      OUTA(5) = OUTA(5)+ASP(I)                                          OUTP0910
      OUTA(6) = OUTA(6)+HSLS(I)                                         OUTP0920
      OUTA(7) = OUTA(7)+PI(I)                                           OUTP0930
      OUTA(8) = OUTA(8)+FLOAT(PI2(I))                                   OUTP0940
      OUTA(9) = OUTA(9)+FAT(I)                                          OUTP0950
      OUTA(10) = OUTA(10)+STRM(I)                                       OUTP0960
      OUTA(11) = OUTA(11)+CAL(I)                                        OUTP0970
  430 OUTA(12) = OUTA(12)+PWR(I)                                        OUTP0980
      DO 435 I=1,12                                                     OUTP0990
  435 OUTA(I) = OUTA(I)/FLIC                                            OUTP1000
      WRITE(6,9417) (OUTA(I),I=1,12)                                    OUTP1010
 9417 FORMAT(' AVGS/MAN',/,2X,F8.3,F9.3,F10.3,F7.3,F8.3,F12.3,F8.3,F5.1,
     1 F8.3,F10.3,F9.0,F7.1)
       TOUTA(3,K)=TOUTA(3,K)+THS(I)                                     OUTP1040
      RETURN                                                            OUTP1050
      ENTRY XXIN                                                        OUTP1060
      NREI=0                                                            OUTP1070
                                                                        OUTP1080
      COTI=0.0                                                          OUTP1090
      CARTI=0.0                                                         OUTP1100
      CDTI=0.0                                                          OUTP1110
       DO 437 I=1,40                                                    OUTP1120
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      DO 437 J=1,10                                          OUTP1130
  437  CLSDTI(J,I)=0.0                                        OUTP1140
       DO 460 I=1,10                                          OUTP1150
       DO 440 J=1,35                                          OUTP1160
  440  IITER(J,I)=0.0                                         OUTP1170
       DO 460 KK=1,13                                         OUTP1180
      DO 450 J=1,21                                           OUTP1190
  450 IMTAB(KK,J,I) = 0.0                                     OUTP1200
       DO 460 J=1,10                                          OUTP1210
  460  TIITER(KK,J,I)=0.0                                     OUTP1220
       RETURN                                                 OUTP1230
       ENTRY OUTP2                                            OUTP1240
       DO 2000 J=1,13                                         OUTP1250
       DO 1998 I=1,10                                         OUTP1260
 1998  TOUTA(J,I)=0.0                                         OUTP1270
 2000 OUTA(J)=0.0                                             OUTP1280
       DO 2010 I=1,IC                                         OUTP1290
       K=IPS(I)                                               OUTP1300
       TEM3(I)=24.0-DS(I)-TW(I)                               OUTP1310
      IMTAB(1, I,ITER) = IMTAB(1, I,ITER) + PCC              OUTP1320
       OUTA(1)=OUTA(1)+PCC(I)                                 OUTP1330
       TOUTA(1,K)=TOUTA(1,K)+PCC(I)                           OUTP1340
      IMTAB(2, I,ITER) = IMTAB(2, I,ITER) + TWP(I)           OUTP1350
       OUTA(2)=OUTA(2)+TWP(I)                                 OUTP1360
       TOUTA(2,K)=TOUTA(2,K)+TWP(I)                           OUTP1370
      IMTAB(3, I,ITER) = IMTAB(3, I,ITER) + TWS(I)           OUTP1380
       OUTA(3)=OUTA(3)+TWS(I)                                 OUTP1390
      TOUTA(3,K)=TOUTA(3,K)+TWS(I)                            OUTP1400
      IMTAB(4, I,ITER) = IMTAB(4, I,ITER) + DS(I)            OUTP1410
       OUTA(4)=OUTA(4)+DS(I)                                  OUTP1420
       TOUTA(4,K)=TOUTA(4,K)+DS(I)                            OUTP1430
      IMTAB(5, I,ITER) = IMTAB(5, I,ITER) + TEM3(I)          OUTP1440
       OUTA(5)=OUTA(5)+TEM3(I)                                OUTP1450
       TOUTA(5,K)=TOUTA(5,K)+TEM3(I)                          OUTP1460
      IMTAB(6, I,ITER) = IMTAB(6, I,ITER) + FAT(I)           OUTP1470
      OUTA(6)=OUTA(6)+FAT(I)                                  OUTP1480
       TOUTA(6,K)=TOUTA(6,K)+FAT(I)                           OUTP1490
      IMTAB(7, I,ITER) = IMTAB(7, I,ITER) + PI(I)            OUTP1500
      OUTA(7)=OUTA(7)+PI(I)                                   OUTP1510
       TOUTA(7,K)=TOUTA(7,K)+PI(I)                            OUTP1520
      IMTAB(8, I,ITER) = IMTAB(8, I,ITER) + APW(I)           OUTP1530
      OUTA(8)=OUTA(8)+APW(I)                                  OUTP1540
       TOUTA(8,K)=TOUTA(8,K)+APW(I)                           OUTP1550
      IMTAB(9, I,ITER) = IMTAB(9, I,ITER) + PCOM(I)          OUTP1560
      OUTA(9)=OUTA(9)+PCOM(I)                                 OUTP1570
       TOUTA(9,K)=TOUTA(9,K)+PCOM(I)                          OUTP1580
      IMTAB(10, I,ITER) = IMTAB(10, I,ITER) + CASP(I)        OUTP1590
      OUTA(10)=OUTA(10)+CASP(I)                               OUTP1600
       TOUTA(10,K)=TOUTA(10,K)+CASP(I)                        OUTP1610
      OUTA(11)=OUTA(11)+IDC(I)                                OUTP1620
      IMTAB(11, I,ITER) = IMTAB(11, I,ITER) + PERF(I)        OUTP1630
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      OUTA(12)=OUTA(12)+PERF(I)                                    OUTP1640
       TOUTA(11,K)=TOUTA(11,K)+PERF(I)                             OUTP1650
      INTAB(12, I,ITER) = INTAB(12, I,ITER) + NU(I)                OUTP1660
      TOUTA(12,K) = TOUTA(12,K)+NU(I)                              OUTP1670
2010  OUTA(13)=OUTA(13)+NU(I)                                      OUTP1680
       DO 2020 I=1,13                                              OUTP1690
       DO 2015 J=1,10                                              OUTP1700
       K=NTIPE(J)                                                  OUTP1710
       IF (K.NE.  0) TOUTA(I,J)=TOUTA(I,J)/FLOAT(K)                OUTP1720
2015   CONTINUE                                                    OUTP1730
       OUTA(I)=OUTA(I)/FLIC                                        OUTP1740
2020  CONTINUE                                                     OUTP1750
       DALY(1,ND)=NSUC1                                            OUTP1760
       DALY(2,ND)=NSUC2                                            OUTP1770
       DALY(3,ND)=NFALE                                            OUTP1780
       DALY(4,ND)=NIGNR                                            OUTP1790
       DALY(5,ND)=OUTA(2)                                          OUTP1800
        DALY(6,ND)=OUTA(3)                                         OUTP1810
       DALY(7,ND)=OUTA(4)                                          OUTP1820
       DALY(8,ND)=OUTA(5)                                          OUTP1830
       DALY(9,ND)=KONC(1)                                          OUTP1840
       DALY(10,ND)=KONC(2)                                         OUTP1850
       DALY(11,ND)=KONC(3)                                         OUTP1860
       DALY(12,ND)=OUTA(8)                                         OUTP1870
       DALY(13,ND)=CHL                                             OUTP1880
       DALY(14,ND)=OUTA(9)                                         OUTP1890
      DALY(15,ND) = APA                                            OUTP1900
       DALY(16,ND)=OUTA(6)                                         OUTP1910
      DALY(17,ND) = OUTA(10)                                       OUTP1920
       DALY(18,ND)=OUTA(7)                                         OUTP1930
       DALY(19,ND)=SI                                              OUTP1940
      DALY(20,ND) = NPRFM(3)                                       OUTP1950
      DALY(21,ND) = NPRFM(4)                                       OUTP1960
       DALY(22,ND)=NREPT                                           OUTP1970
      DALY(23,ND) = HRSR                                           OUTP1980
      DALY(24,ND) = HRSE                                           OUTP1990
      DALY(25,ND) = MAXST                                          OUTP2000
      DALY(26,ND) = CMLMX                                          OUTP2010
       DALY(27,ND)=PEFF                                            OUTP2020
      DALY(28,ND) = TEH                                            OUTP2030
      DALY(29,ND) = SFDIFF                                         OUTP2040
      DALY(30,ND) = NSUC1 + NSUC2                                  OUTP2050
      DALY(31,ND) = USHT                                           OUTP2060
      DALY (32,ND) = ICSS                                          OUTP2070
      IOMAX = NEURE                                                OUTP2080
      DO 2034 I=1,IOMAX                                            OUTP2090
      CUTI=CUTI + CUT(I)                                           OUTP2100
      CDTI=CDTI + CDT(I)                                           OUTP2110
2034   CARTI=CARTI + CART(I)                                       OUTP2120
      NREI=NREI + NR                                               OUTP2130
      DO 2032 I=1,10                                               OUTP2140
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      ADALY(I,ND) = KONC(I)
      IDALY1 (I,ND) = KONC1 (I)
 2032 CONTINUE
       DO 2025 J=1,10
       DO 2025 I=1,12
 2025  YDALY(I,J,ND)=YOUTA(I,J)
      DO 2022 I=1,40
       DO 2022 J=1,9
       CLSDTR(J,I)=CLSDTR(J,I) + CLSDTA(J,I)
 2022  CLSDTI(J,I)=CLSDTI(J,I) + CLSDTA(J,I)
       IF(IND(6).WT.ND) RETURN
 1990 NPRFM(1) = NPRFM(1)+NIGNR
      FNTE = NPRFM(1)
      N1S1=NSUC1+NSUC2
       TEM1=HRSS+HRSR+HRSE
      T3(1)=FLOAT(NFALE)/FNTE*100.0
       T3(2)=FLOAT(NSUC1)/FNTE*100.0
      T3(3)=FLOAT(NSUC2)/FNTE*100.0
      T3(4)=FLOAT(NIGNR)/FNTE*100.0
      T3(5)=FLOAT(NREPT)/FNTE*100.0
      DO 2026 I=1,10
      IKONC(I)=KONC(I)
 2026 CONTINUE
       WRITE(6,9984) ND,ITER,(NPRFM(I),I=1,4),NREPT,N1S1,NFALE,NIGNR,
     1 TEM1,HRSS,HRSR,HRSE,USHT,APA,SFDIFF,
     1 (T3(I),I=1,5),SI,CI,CML,PEFF,TEM,REPTM,
     2                 MAXST,MAXSTE,CMLMX,ICML,SIDCMX,IDCMX,ICSS
     3 ,(KONC1(I),I=1,10),(IKONC(I),I=1,10)
 9984 FORMAT(15H1REPORT FOR DAYI3,11H, ITERATIONI3/19H  NO. EVENTS--TOTA
     1LI4,12H   SCHEDULEDI4,9H   REPAIRI4,12H   EMERGENCYI4,10H   REPEAT
     2SI4,12H   SUCCESSESI4,11H   FAILURESI4,10H   IGNORESI4/22H  HOURS
     3WORKED---TOTALF6.1,11H  SCHEDULEDF6.1,8H  REPAIRF6.1,7H  EMER.
     4F6.1,10H  UNMANNEDF7.1,15H  AVG PERF ADEQF5.2,14H AVG FAIL DIFF
     5 F6.3/  25H  PERCENTAGE OF---FAILUREF5.1,                15H  SUCC
     6. 1ST TRYF5.1,15H  SUCC. 2ND TRYF5.1,9H  IGNOREDF5.1,9H  REPEATSF5
     7.1/14H  SAFETY INDEXF6.2,16(1H ),1A6,13H  MENTAL LOAD
     8 F8.2,10H  PERF EFF F9.3,8H  HAZARD,F7.0,'  EQUIPMENT REPAIR',
     8 ' TIME ',F4.1/
     913H  MAX. STRESSF6.2,9H ON EVENTI4,18H  MAX. MENTAL LOADF4.0,
     A9H ON EVENTI4,20H  MAX. CAL. EXPENDEDF9.0,9H ON EVENTI4,10H SEA ST
     BATE I3/23H CONS. BAL. (UNITS)    10I7/23H CONS. BAL. (UNITS/HR) 10
     C I7)
       WRITE(6,9985)
 9985 FORMAT(125HUMAN  TYPE  PHYSICAL  HOURS WORKED  SLEPT  IDLE  FATIGU
     1E  HEALTH  AVG PHYS  COMPETENCE  ASPIRATION   PERFORM  NUMBER
     2    /4H NO.,10X,4HCAP,4X,12HPRIM.     2ND,25X,5HINDEX,2X,8HWORKLOAD
     329X,4HCUM.,4X,5HSUCC.)
       DO 1991 I=1,IC
       WRITE(6,9987) I,IPS(I),PCC(I),TWP(I),TWS(I),DS(I),TEM3(I),FAT(I),
     1PI(I),APH(I),PCOM(I),CASP(I),        PERF(I),NU(I)
 9987 FORMAT(1H ,I3,I6,F10.3,2F7.2,F7.1,F6.1,F9.2,F8.2,F10.2,F12.3,
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      1F12,2,        F9,2,F8.0)
 1991  CONTINUE
       WRITE(6,9988) (OUTA(I),I=1,10),OUTA(12),OUTA(13)
 9988  FORMAT(9H0AVERAGES/9H  PER MANF11.3,2F7.2,F7.1,F6.1,F9.2,F8.2,
     1 F10.2,F12.3,F12.2,F9.2,F10.2)
       WRITE(6,9989)
 9989 FORMAT(1H0//17H0AVERAGES BY TYPE/11H   NO   TYPE)
       DO 1995 I=1,10
       K=NTIPE(I)
       IF(K,EQ,0) GO TO 1995
      WRITE(6,9990) K,I,(TOUTA(J,I),J=1,12)
 9990  FORMAT(2I5,    F10.3,2F7.2,F7.1,F6.1,F9.2,F8.2,F10.2,F12.3,F12.2,
     1 F9.2,F8.2)
 1995  CONTINUE
       WRITE(6,1996) (I,CART(I),CDT(I),CUT(I),EPL(I),I=1,IQMAX)
 1996 FORMAT(//1H0,'DAILY PERFORMANCE OF EQUIPMENT',/,
     1 17X,'AVG. REPAIR TIME    UP   PERFORMANCE'/,
     2 7X,'EQUIPMENT EXPECTED   ACTUAL TIME  LEVEL  EFFIC',
     3 /,(11X,I2,5X,F5.2,5X,F5.2,1X,F5.2,2X,F5.2,'     -'))
      ACART(1)=0.
      ACDT(1)=0.
      ACUT(1)=0.
      DEPEFF(ND)=EPEFF
      DO 2150 I=1,IQMAX
      ACART(ND)=CART(I)/IQMAX+ACART(ND)
      ACDT(ND)=ACDT(ND)+CDT(I)/IQMAX
      ACUT(ND)=ACUT(ND)+CUT(I)/IQMAX
 2150 CONTINUE
      WRITE(6,1997) ACART(ND),ACDT(ND),ACUT(ND),AEPL(ND),
     1 DEPEFF(ND)
 1997 FORMAT(1H0,/,'AVERAGES',10X,F5.2,5X,F5.2,1X,F5.2,2X,F5.2,
     1 2X,F5.2,)
C    1 2X,F5.2,1X,             //' SYSTEM RELIABILITY LEVEL ',F5.2,10X,
C    2 ' SYSTEM PERFORMANCE LEVEL ',F5.2,10X,'   SYSTEM EFFECTIVENESS ME
C    3ASURE ',F5.2)
      WRITE(6,2159)
 2159 FORMAT(1H1,'SUMMARY BY EVENT CLASS',/,' EVENT      NO. OF    HOURS
     1WORKED      ----PERCENT OF TIME---   PERFORM. AVG. FAILURE'/' CLASS
     2      EVENTS        PRIM     2ND     SUC1  SUC2  FAIL  IGNORE  ADEQUACY
     3 DIFFERENCE')
      DO 40 I=1,40
      IF(CLSDTA(1,I).LE.0.0) GO TO 40
      DO 30 J=2,9
   30  CLSDTA(J,I)= CLSDTA(J,I)/CLSDTA(1,I)
      DO 35 J=2,5
      IPERCT(J)=CLSDTA(J,I)*100.+.5
   35 CONTINUE
      WRITE(6,2160) I,CLSDTA(1,I),CLSDTA(6,I),CLSDTA(7,I),
     1 IPERCT(2),IPERCT(3),IPERCT(4),IPERCT(5),
     2 CLSDTA(8,I),CLSDTA(9,I)
 2160  FORMAT(I6,F10.0,F10.2,F9.2,I5,2I6,I8, F9.2,F12.2)
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   40 CONTINUE                                                    OUTP3140
      RETURN                                                      OUTP3150
      ENTRY OUTP3                                                 OUTP3160
 2030 WRITE(6,9029) ITER,NDMAX                                    OUTP3170
 9029 FORMAT(21H1REPORT FOR ITERATIONI3,3H OFI3,15H DAY MISSION---/ OUTP3180
     2 127H DAY     NUMBER OF EVENTS        AVE. MAN HOURS SPENT  OUTP3190
     3              ----------END OF DAY AVERAGES----------  INDICESOUTP3200
     4/5X,125H SUC1 SUC2 FAIL IGNORE  PRIM. SECOND  SLEEP   IDLE  OUTP3210
     5                   PHYS LD  MEN LD  COMP  APA   FAT.  ASP  HLTH  SFTOUTP3220
     6Y/)                                                         OUTP3230
      DO 2031 J=1,NDMAX                                           OUTP3240
 2031 WRITE (6,9030) J, (DALY(I,J),I=1,8),(DALY(I,J),I=12,19)     OUTP3250
 9030 FORMAT (I4,1X,3F5.0,F7.0,4F7.2,24X,  F8.2,F8.2,F6.3,F6.2,   OUTP3260
     1 F6.2,F5.2,2F6.2)                                           OUTP3270
      FD=NDMAX                                                    OUTP3280
      TOT=0.0                                                     OUTP3290
      DO 2055 I=1,NDMAX                                           OUTP3300
      DO 2055 J=1,4                                               OUTP3310
      TOT=TOT+DALY(J,I)                                           OUTP3320
 2055 IITER(J,ITER)=IITER(J,ITER)+DALY(J,I)                       OUTP3330
      DO 2056 J=1,4                                               OUTP3340
 2056 IITER(J,ITER)=IITER(J,ITER)/TOT*100.0                       OUTP3350
      DO 2058 J=5,8                                               OUTP3360
      DO 2057 I=1,NDMAX                                           OUTP3370
 2057 IITER(J,ITER)=IITER(J,ITER)+DALY(J,I)                       OUTP3380
 2058  IITER(J,ITER)=IITER(J,ITER)/FD                             OUTP3390
      DO 2061 I=1,10                                              OUTP3400
      JITER(I,ITER) = KONC(I)/KON(I) *100.0                       OUTP3410
      ZTEM = KONC1(I)                                             OUTP3421
      JITER(I+10,ITER) = ZTEM    /KON1(I) *100.0                  OUTP3430
 2061 CONTINUE                                                    OUTP3440
      DO 2060 J=12,19                                             OUTP3450
      DO 2059 I=1,NDMAX                                           OUTP3460
 2059 IITER(J,ITER)=IITER(J,ITER)+DALY(J,I)                       OUTP3470
 2060  IITER(J,ITER)=IITER(J,ITER)/FD                             OUTP3480
      WRITE(6,9031) (IITER(I,ITER),I=1,8),(IITER(I,ITER),I=12,19) OUTP3490
 9031  FORMAT(1H /5X,22H---PERCENT OF TOTAL---4X,'AVERAGE PER DAY PER MA
     1N',49X,'AVERAGE PER DAY',/
     2 5X,3F5.1,F7.1,4F7.2,24X,  2F8.2,F6.3,F6.2,F6.2,F5.2,2F6.2,//) OUTP3520
      DO 3010 J=1,NDMAX                                           OUTP3530
      DO 3035 I=1,10                                              OUTP3540
      IPERCT(I)=ADALY(I,J)+.5                                     OUTP3550
 3035 CONTINUE                                                    OUTP3560
      WRITE(6,3040) (IPERCT(I),I=1,10)                            OUTP3570
 3040 FORMAT(24H CONS. BAL. (UNITS/HR)  10I7)
 3010 CONTINUE                                                    OUTP3590
      DO 3015 I=1,10
      IPERCT(I)=JITER(I,ITER)+.5
 3015 CONTINUE
      WRITE(6,93050) (IPERCT(I),I=1,10)
93050 FORMAT(24H PERCENT OF ORIGINAL    ,10I7)                    OUTP3640
```

```
      DO 3020 J=1,NDMAX                                                 OUTP3650
      WRITE (6,3030) (IDALY1(I,J),I=1,10)                               OUTP3660
 3030 FORMAT(24H CONS, BAL, (UNITS)      10I7)                          OUTP3670
 3020 CONTINUE                                                          OUTP3680
      DO 3025 I=1,10                                                    OUTP3690
      IPERCT(I)=JITER(I+10,ITER)+.5                                     OUTP3700
 3025 CONTINUE                                                          OUTP3710
      WRITE(6,93050) (IPERCT(I),I=1,10)                                 OUTP3720
      WRITE(6,90315)                                                    OUTP3730
90315 FORMAT(//9X,'-----NUMBER OF EVENTS------  AVE. MAN HOURS SPENT  ',
     1 'REPAIR   MAX,    MAX,    PERF,',11X,'AVE,FL  NUMBER    UNMANNED'
     2,'  SEAT/4X,'DAY  SCHLD REPAIR EMER  REPEAT REPAIR SUC2 EMERGENCY'OUTP3760
     3,'   TIME   STRESS  MEN LD   EFF;  HAZARD   DIFF    SUCC,',5X,    OUTP3770
     4 'HOURS   STATE'/)                                                OUTP3780
      DO 2062 J=1,NDMAX                                                 OUTP3790
      DO 3050 I=1,3                                                     OUTP3800
      IPERCT(I)=DALY(I+19,J)+.5                                         OUTP3810
 3050 CONTINUE                                                          OUTP3820
      IPERCT(4)=DALY(30,J)                                              OUTP3830
C   C WRITE(6,90316) J,NOSE,(DALY(I,J),I=20,23),RSSUC2,DALY(24,J),      OUTP3840
C    1 REPTM,(DALY(I,J),I=25,32)                                        OUTP3850
      WRITE(6,90316) J,NOSE,(IPERCT(I),I=1,3),DALY(23,J),               OUTP3860
     1 RSSUC2,DALY(24,J),REPTM,(DALY(I,J),I=25,29),                     OUTP3870
     2 IPERCT(4),(DALY(I,J),I=31,32)                                    OUTP3880
      DO 2062 I=20,32                                                   OUTP3890
 2062 IITER(I,ITER) = IITER(I,ITER)+DALY(I,J)                           OUTP3900
90316 FORMAT(4X,I3,3X,I3,I5,2X,I5,1X,I5,5X,F4,1,   F6,2,1X,F4,1,6X,     OUTP3910
     1F6,2,4X,F4,2,3X,F5,2,3X,F5,3,3X,F6,2,2X,F5,2,3X,  I4,6X,F6,2,F7,1)OUTP3920
      DO 2063 I=20,29                                                   OUTP3930
 2063 IITER(I,ITER) = IITER(I,ITER)/FD                                  OUTP3940
      IITER (32,ITER) = IITER (32,ITER)/FD                              OUTP3950
      IITER(31,ITER) = IITER(31,ITER)/FD                                OUTP3960
90317 FORMAT(1H0, 'AVG/DAY',2I5,I7,I6,F9,1,
     1 F6,2,F5,1,F12,2,2F8,2,
     2 F8,3,F9,2,F7,2,I7,F12,2,F7,1)
      DO 2068 I=1,3                                                     OUTP4000
 2068 CONTINUE                                                          OUTP4010
      IPERCT(I)=IITER(I+19,ITER)                                        OUTP4020
      REPTMD=REPTM/ND                                                   OUTP4030
      RSSUC2D=RSSUC2/ND                                                 OUTP4040
      RSTOT=RSTOT+RSSUC2D
      IPERCT(4)=IITER(30,ITER)                                          OUTP4050
      WRITE(6,90317) NOSE,(IPERCT(I),I=1,3),IITER(23,ITER),RSSUC2D,     OUTP4060
     1 IITER(24,ITER),REPTMD,(IITER(I,ITER),I=25,29),IPERCT(4),         OUTP4070
     2 (IITER(I,ITER),I=31,32)                                          OUTP4080
       WRITE(6,9034)                                                    OUTP4090
 9034 FORMAT( ///  30H0AVERAGES BY TYPE OF PERSONNEL/)                  OUTP4100
      WRITE(6,9032)                                                     OUTP4110
 9032  FORMAT(   127H0NO.  TYPE  PHYSICAL  HOURS WORKED  SLEPT  IDLE  FA
     1TIGUE  HEALTH  AVG PHYS  COMPETENCE  ASPIRATION    PERFORM
     2     NUMBER,/14X,4HCAP,4X,12HPRIM,     2ND,25X,5HINDEX,2X,
```

```
      3 8HWORKLOAD,30X,4HCUM,,13X,5HSUCC,)
        DO 2065 I=1,NDMAX
        DO 2065 J=1,10
        K=NTIPE(J)
        IF(K.EQ.0) GO TO 2065
 9033   FORMAT(1H I2,I6,F11.3,2F7.2,F7.1,F6.1,F9.2,F8.2,F10.2,F12.3,
      1 F12.2,10X,F9.2,F8.2)
        DO 2064  KK=1,12
 2064   TIITER(KK,J,ITER)=TIITER(KK,J,ITER)+TDALY(KK,J,I)
 2065   CONTINUE
        DO 2067 J=1,10
        K=NTIPE(J)
        IF(K.EQ.0) GO TO 2067
        DO 2066 I=1,11
 2066   TIITER(I,J,ITER)=TIITER(I,J,ITER)/FD
       WRITE(6,9991)K,J,(TIITER(I,J,ITER),I=1,12)
 9991   FORMAT(I4,I5,F11.3,F10.3,2F7.2,F7.1,F6.1,F9.2,F8.2,F10.2,F12.3,
      1 F12.2,10X,F9.2)
 2067   CONTINUE
 2070   CONTINUE
       T3(1)=CUTI/(CUTI+CDTI)
       T3(2)=CARTI/FLOAT(NREI)
       REMTB=REMTR + T3(1)
       REMTR=REMTR + T3(2)
       IF(IND(7).EQ.0) RETURN
       WRITE(6,9275)
 9275  FORMAT(30H0AVERAGES PER DAY FOR EACH MAN/)
       DO 2072 I=1,12
 2072  OUTA(I)=0.0
       DO 2080 I=1,IC
       DO 2075 J=1,12
       IMTAB(J,I,ITER) = IMTAB(J,I,ITER)/FD
 2075  OUTA(J)=OUTA(J)+IMTAB(J,I,ITER)
 2080  WRITE(6,9991) I,IPS(I),(IMTAB(J,I,ITER),J=1,12)
       DO 2082 I=1,12
 2082  OUTA(I)=OUTA(I)/FLIC
       WRITE(6,9996) (OUTA(I),I=1,12)
 9996  FORMAT(10H0AVERAGES
      1 2F10.3,2F7.2,F7.1,F6.1,F9.2,F8.2,F10.2,F12.3,F12.2,10X,F9.2)
C       WRITE(6,9997) T3(1), T3(2)
C9997  FORMAT(//1H0,'EQUIPMENT MEAN TIME BETWEEN FAILURES ',F8.3,
C     1 '    EQUIPMENT MEAN TIME TO REPAIR',F8,3)
       AVACA=0.
       AVACD=0.
       AVACU=0.
       AVAEP=0.
       AVDEP=0.
       DO 2095 I=1,NDMAX
       AVACA=ACART(I)/NDMAX+AVACA
       AVACD=ACDT(I)/NDMAX+AVACD
       AVACU=ACUT(I)/NDMAX+AVACU
```

```
      AVAEP=AEPL(I)/NDMAX+AVAEP
      AVDEP=DEPEFF(I)/NDMAX+AVDEP
 2095 CONTINUE
      WRITE(6,2159)
       DO 2084 I=1,40
      IF( CLSDTI(1,I).LE. 0.0) GO TO 2084
      DO 2083 J=2,9
 2083  CLSDTI(J,I)= CLSDTI(J,I) / CLSDTI(1,I)
      DO 2090 IFM=1,4
      IPERCT(IFM)=CLSDTI(IFM+1,I)*100.+.5
 2090 CONTINUE
      WRITE(6,2160) I,CLSDTI(1,I),CLSDTI(6,I),CLSDTI(7,I),
     1 (IPERCT(IFM),IFM=1,4),CLSDTI(8,I),CLSDTI(9,I)
 2084  CONTINUE
      WRITE(6,9800)ITER, (I,ACART(I),ACDT(I),ACUT(I),AEPL(I),DEPEFF(I),
     1 I=1,NDAYS)
C    1 DEMTBF(I),DEMTTR(I),I=1,NDAYS)
 9800 FORMAT(1H ,////,'EQUIPMENT PERFORMANCE FOR ITERATION',I3,//,
     1 'DAY  AVG. REPAIR TIME/EQUIP      UP       PERFORMANCE',/,
     2 7X,'EXPECTED     ACTUAL',6X,'TIME      LEVEL EFFIC',/
     3 (I2,2F11.2,F10.2,F9.2,F6.2))
      WRITE(6,9805) AVACA,AVACD,AVACU,AVAEP,AVDEP
 9805 FORMAT(1H ,/,'AVG.', F9.2,F11.2,F10.2,F9.2,F6.2)
      RETURN
       ENTRY OUTP4
       FLITER=ITER
       WRITE(6,9555) ITER,NDMAX
 9555  FORMAT(16H1RUN SUMMARY FORI3,14H ITERATIONS OFI3,12H-DAY MISSION/
     1 127H ITER     NUMBER OF EVENTS          AVE. MAN HOURS SPENT
     1                    ----------END OF DAY AVERAGES-----------  INDICES
     2/9X,125H SUC1  SUC2 FAIL IGNORE  PRIM. SECOND  SLEEP   IDLE
     3                     PHYS LD  MEN LD  COMP   APA  FAT.  ASP  HLTH  SFT
     4//5X,22H---PERCENT OF TOTAL---6X,15HAVERAGE PER DAY7X,
     5 24H                    18X,15HAVERAGE PER DAY)
       DO 2105 I=1,32
 2105  OUTA(I)=0
       DO 2110 I=1,ITER
       WRITE(6,9556) I,(IITER(J,I),J=1,8),(IITER(J,I),J=12,19)
 9556 FORMAT(I4,1X,3F5.1,F7.1,4F7.2,24X, 2F8.2,F6.3,F6.2,F6.2,F5.2,
     12F6.2)
      DO 2108 J=1,32
 2108  OUTA(J)=OUTA(J)+IITER(J,I)
      DO 2109 J=1,10
      OUTB(J) = OUTB(J) + JITER(J,I)
      OUTB (J+10) = OUTB(J+10) + JITER(J+10 ,I)
 2109 CONTINUE
 2110 CONTINUE
       DO 2115 J=1,32
 2115  OUTA(J)=OUTA(J)/FLITER
       WRITE(6,9557) (OUTA(I),I=1,8),(OUTA(I),I=12,19)
 9557 FORMAT (19H0AVERAGES/ITERATION/
```

```
1         5X,3F5.1,      5F7.2,24X,  F8.2,F8.2,F6.3,F6.2,F6.2,F5.2,  OUTP4970
2 2F6.2)                                                              OUTP4980
  WRITE(6,3070) (I,I=1,10),(I,I=1,10),(I,(JITER(J,I),J=1,20),         OUTP4990
1 I=1,ITER)                                                           OUTP5000
3070 FORMAT(//' CONSUMABLES BALANCE - PERCENTAGE OF ORIGINAL'/26X,    OUTP5010
1 '(UNITS PER HOUR)',47X,'(UNITS)',/'ITER',1X,10I6,4X,10I6,/,
2 (I3,3X,10F6.1,4X,10F6.1))
  DO 3075 I=1,20                                                      OUTP5040
  OUTB(I)=OUTB(I)/ITER                                                OUTP5050
3075 CONTINUE                                                         OUTP5060
  WRITE(6,3080) (OUTB(I),I=1,20)                                      OUTP5070
3080 FORMAT(1H ,/,'  AVG.',     10F6.1,4X,10F6.1)
  WRITE(6,9115)                                                       OUTP5090
9115 FORMAT (//131H ITER  NUMBER OF EVENTS    AVE. MAN HOURS SPENT   MOUTP5100
1AX STRESS  MAX MEN LD   PERF EFF  HAZARD      AVG FAIL  NUMBER   UN
2MANNED   SEA / 8X,40HREPAIR   EMER     REPT  REPAIR EMERGENCY,52X,
3 'DIFF',5X,'SUCC.      HOURS STATE')
  DO 9116 I=1,ITER                                                    OUTP5140
  DO 9117  IJ=1,3                                                     OUTP5150
  IPERCT(IJ)=IITER(IJ+19,I)                                           OUTP5160
9117 CONTINUE                                                         OUTP5170
  IPERCT(4)=IITER(30,I)                                               OUTP5180
  WRITE(6,90416) I,(IPERCT(J),J=1,3),  (IITER(J,I),J=23,29),          OUTP5190
1 IPERCT(4),(TITER(J,I),J=31,32)                                      OUTP5200
9116 CONTINUE                                                         OUTP5210
90416 FORMAT(I5,1X,I8,1X,I6,I7,      1X,F7.1,1X,F8.1,7X,F8.2,4X,F8.2,4X,OUTP5220
1F8.3,F8.3,4X,F8.3,1X,  I8,2X,F8.3,F7.1)                              OUTP5230
  WRITE(6,90318) (OUTA(I),I=20,32)                                    OUTP5240
90318 FORMAT(1H0,'AVERAGES/ITERATION/DAY',/,                          OUTP5250
1 8X,4F7.1,F9.1,F15.2,F12.2,F12.3,F7.2,F13.3,F10.2,F8.2,F8.1)
  DO 2120 I=1,11                                                      OUTP5270
  DO 2120 J=1,10                                                      OUTP5280
2120 TOUTA(I,J) = 0.0                                                 OUTP5290
9120 FORMAT(///30H0AVERAGES BY TYPE OF PERSONNEL/)                    OUTP5300
  WRITE(6,9120)                                                       OUTP5310
  WRITE(6,9558)                                                       OUTP5320
9558 FORMAT (   125H0      TYPE  PHYSICAL  HOURS WORKED  SLEPT  IDLE  FAOUTP5330
1TIGUE  HEALTH  AVG PHYS  COMPETENCE  ASPIRATION  PERFORM             OUTP5340
2          /14X        ,4HCAP,4X,12HPRIM,      2ND,25X,5HINDEX,2X,    OUTP5350
3 8HWORKLOAD,30X,4HCUM,)                                              OUTP5360
   DO 2125 I=1,ITER                                                   OUTP5370
   DO 2124 J=1,10                                                     OUTP5380
   IF(NTIPE(J).EQ.0) GO TO 2124                                       OUTP5390
   DO 2123 K=1,11                                                     OUTP5400
2123  TOUTA(K,J)=TOUTA(K,J)+TIITER(K,J,I)                             OUTP5410
2124  CONTINUE                                                        OUTP5420
2125  CONTINUE                                                        OUTP5430
                                                                      OUTP5440
  DO 2140 J=1,10                                                      OUTP5450
  IF(NTIPE(J) .EQ. 0)  GO TO 2140                                     OUTP5460
  DO 2130 I=1,11                                                      OUTP5470
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 2130 TOUTA(I,J) = TOUTA(I,J)/FLITER                                   OUTP5480
      WRITE(6,9993)       J,(TOUTA(I,J),I=1,11)                        OUTP5490
 9993  FORMAT(5X,I5, F10.3,2F7.2,F7.1,F6.1,F9.2,F8.2,F10.2,F12.3,F12.2, OUTP5500
     1 F9.2,F8.2)                                                      OUTP5510
 2140 CONTINUE                                                         OUTP5520
      WRITE(6,2159)                                                    OUTP5530
      DO 2144 I=1,40                                                   OUTP5540
      IF(CLSDTR(1,I).LE.0.0) GO TO 2144                                OUTP5550
      DO 2143 J=2,9                                                    OUTP5560
 2143 CLSDTR(J,I) = CLSDTR(J,I) / CLSDTR(1,I)                          OUTP5570
      DO 4150 IFM=1,4                                                  OUTP5580
      IPERCT(IFM)=CLSDTR(IFM+1,I)*100.+.5                              OUTP5590
 4150 CONTINUE                                                         OUTP5600
      CLSDTR(1,I)=CLSDTR(1,I)/ITER                                     OUTP5610
      WRITE(6,2160) I,CLSDTR(1,I),CLSDTR(6,I),CLSDTR(7,I),             OUTP5620
     1 (IPERCT(IFM),IFM=1,4),CLSDTR(8,I),CLSDTR(9,I)                   OUTP5630
 2144  CONTINUE                                                        OUTP5640
C     T3(1) = OUTA(1)/(OUTA(1)+OUTA(2)+OUTA(3)) * (OUTA(5)+OUTA(6))    OUTP5650
C     T3(2) = OUTA(2)*(OUTA(5)+OUTA(6))                                OUTP5660
C     T3(3) = T3(1)/(T3(1) + T3(2))                                    OUTP5670
C     T3(4) = REMTB                                                    OUTP5680
C     T3(5) = REMTR                                                    OUTP5690
C     T3(6) = T3(4)/(T3(4) + T3(5))                                    OUTP5700
C     T3(7) = SQRT(0.5*(T3(3)**2 + T3(6)**2))                          OUTP5710
C     WRITE(6,9140) (T3(I),I=1,7)                                      OUTP5720
C9140 FORMAT(1H0,9HHMMTBF   =,F8.3,5X,8HHMMTTR  =,F8.3,                OUTP5730
C    1 5X,9HHMAVAIL  =,F8.3/                                           OUTP5740
C    2 1X,9HEMTBF   =,F8.3,5X,8HEMTTR  =,F8.3,5X,8HEAVAIL =,F8.3/      OUTP5750
C    3 1X,9HSYSAVAIL=,F8.3)                                            OUTP5760
C                                                                      OUTP5770
      SMTTR=(SCDTIQ+ RSTOT)/(ITER*NDAYS*(OUTA(20)+OUTA(2)/100.))
      EQUPTR=1.-OUTA(20)/24.
      HMNRL=1.-(OUTA(2)+OUTA(3))*NDAYS/100.
      SYSRL=1.-NDAYS/24.*(OUTA(20)+(OUTA(2)+OUTA(3))/100.)
      EQUPTA=(24.-OUTA(23)/IQMAX)/(24.*NDAYS)                          OUTP5830
      HMNAV=1.-OUTA(31)*ITER/(IC*24.)                                  OUTP5840
      SYSA=1.-(SCDTIQ/(24.*ITER*IQMAX*NDAYS))
     1 *(OUTA(31)/(IC*24.*NDAYS))
      IF(OUTA(20).EQ.0.) GO TO 8200
      FEMTBF=(IQMAX*ITER*NDAYS*24.-SCDTIQ)/(OUTA(20)*ITER*NDAYS)       OUTP5860
      GO TO 8210
 8200 FEMTBF=0.
 8210 CONTINUE
      HMTTR= RSTOT/(OUTA(2)*ITER*NDAYS)
      EMTTR=REMTR/ITER
      WRITE(6,8111)                                                    OUTP5890
 8111 FORMAT(1H0,2X,'SUMMARY OF MEASURES OVER ALL ITERATIONS'//,15X,   OUTP5900
     C                                     '- - - - - - - - HUMAN - OUTP5910
     1- - - - -      - - - - - - - EQUIPMENT - - - - - - - -    - - - - - -OUTP5920
     2- SYSTEM - - - - -',/,2X,'             RELIABILITY AVAILABILITY   'OUTP5930
     3TTR       RELIABILITY AVAILABILITY    MTBF     MTTR   RELIABILITY AVAILOUTP5940
```

```
      4ABILITY   MTTR')                                                 OUTP5950
       WRITE(6,8112)   HMNRL,HMNAV,HMTTR,EQUPTR,EQUPTA,                 OUTP5960
      1 FEMTBF,EMTTR,SYSRL,SYSA,SMTTR                                   OUTP5970
 8112 FORMAT (1X,6X,10X,F6.3,7X,F6.3,3X,F8.2,6X,F6.3,7X,F6.3,3X,        OUTP5980
      1 F6.1,1X,F6.1,6X,F6.3,7X,F6.3,3X,F7.2)                           OUTP5990
       WRITE(6,8113)  RSTOT,SCDTIQ                                      OUTP6000
 8113 FORMAT(1H1, ' RSSUC2=',F8.1,'   SCDTIQ=',F8.1)                    OUTP6010
       WRITE(6,8114) NDAYS,ITER,OUTA(23),OUTA(20),OUTA(31),             OUTP6020
      1 OUTA(2),OUTA(3)                                                 OUTP6030
 8114 FORMAT(1H ,' NDAYS=',I3,10X,' ITER=',I3,10X,' A=',F6.2,           OUTP6040
      1 ' C=',F6.2,//,'D=',F6.2,10X,'G=',F6.2,10X,'H=',F6.2)            OUTP6050
        RETURN                                                          OUTP6060
       END                                                              OUTP6070
```

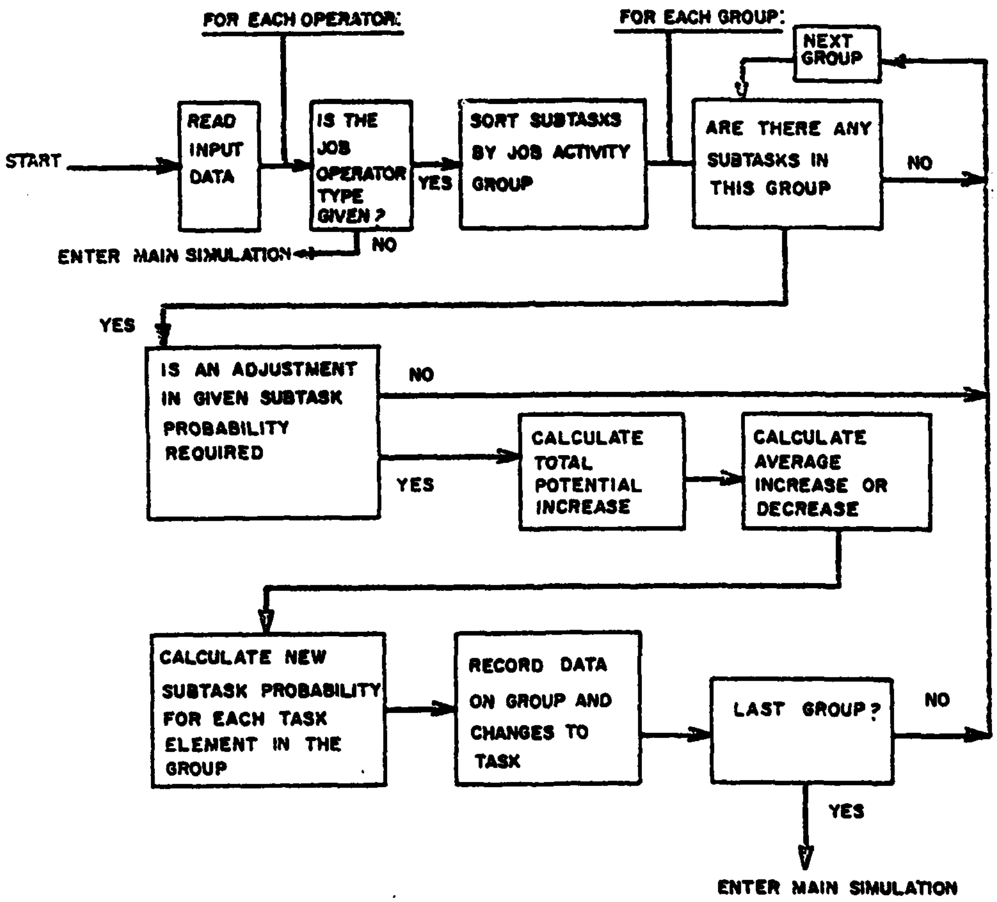
APPENDIX C PROGRAM FLOWCHARTS

This appendix contains the program flowcharts for the digital simulation models as follows:

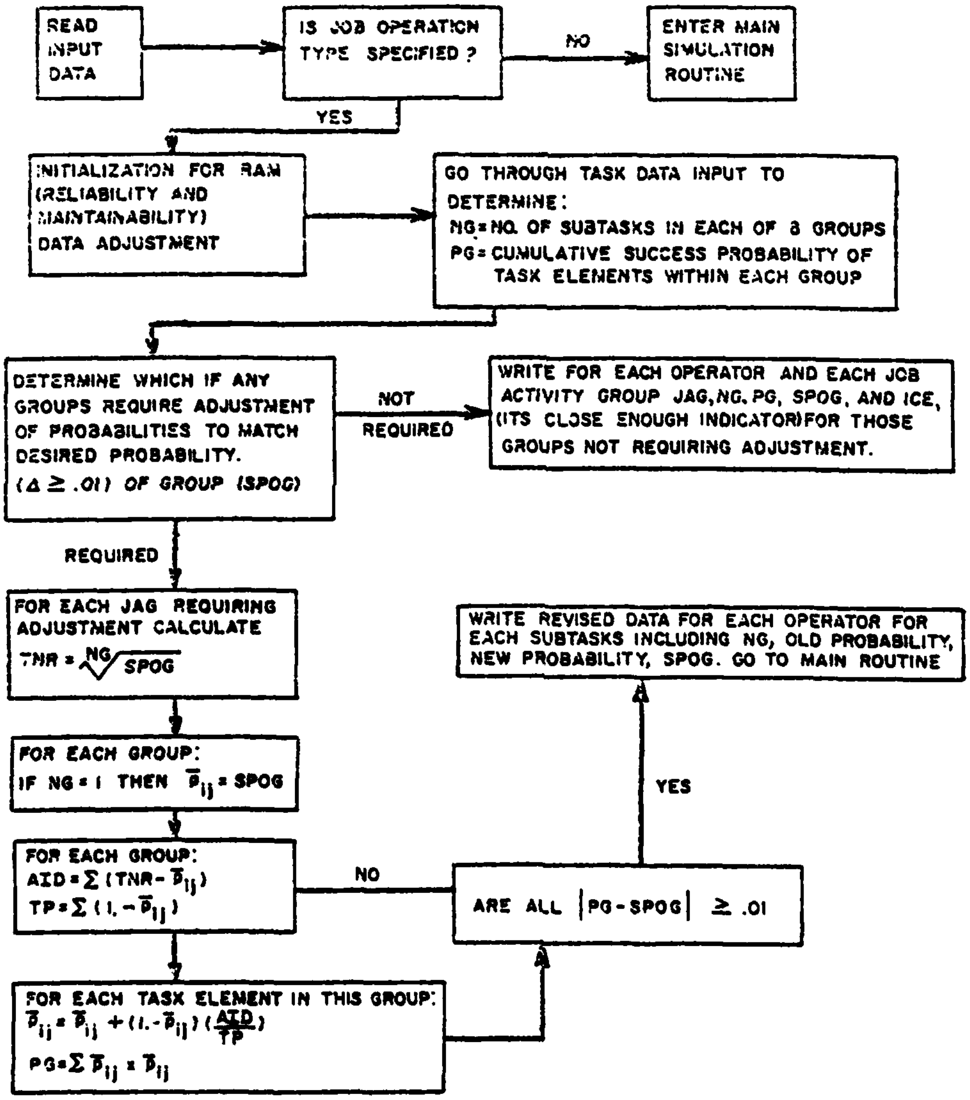
- Appendix C1 - 1-2 man digital simulation model
- Appendix C2 - 4-20 man digital simulation model

APPENDIX C1 - PROGRAM FLOWCHART

This appendix contains the flowchart for the digital simulation program.

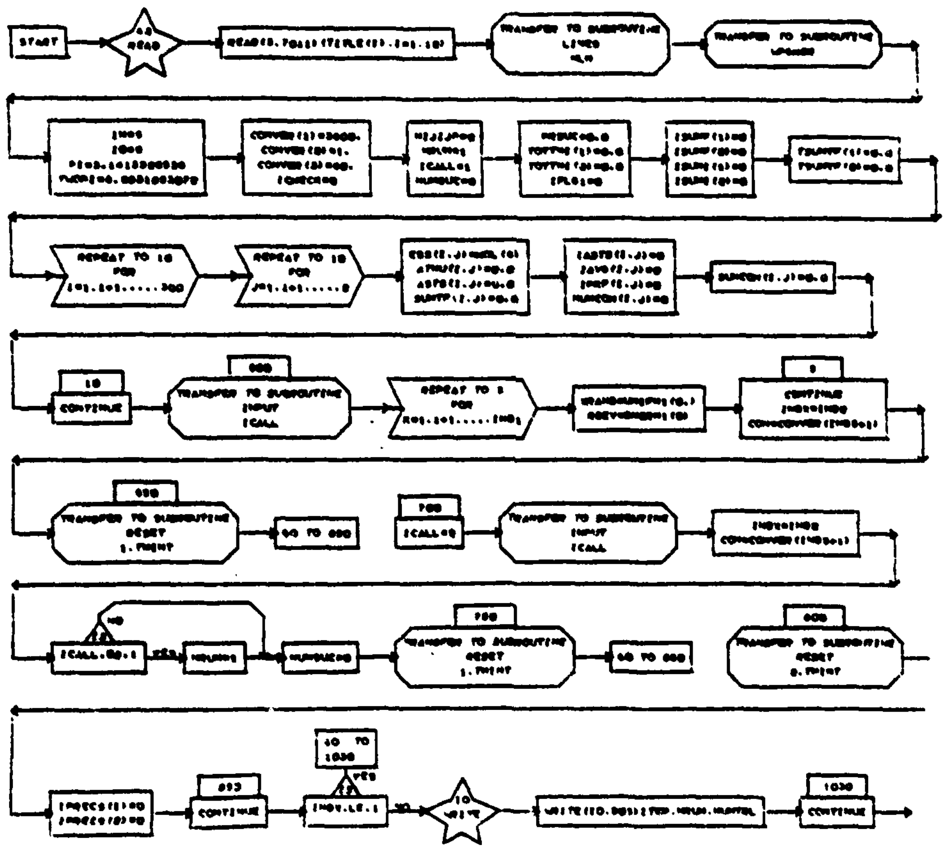


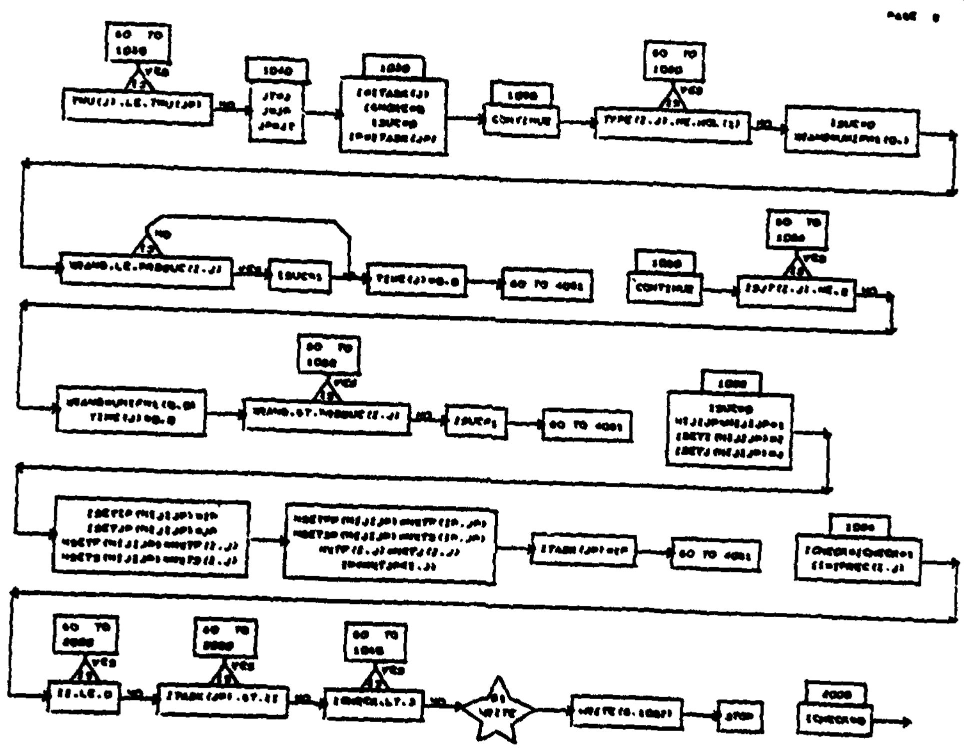
Summary flow chart of preprocessor



Basic programming elements for preprocessor

Main Routine





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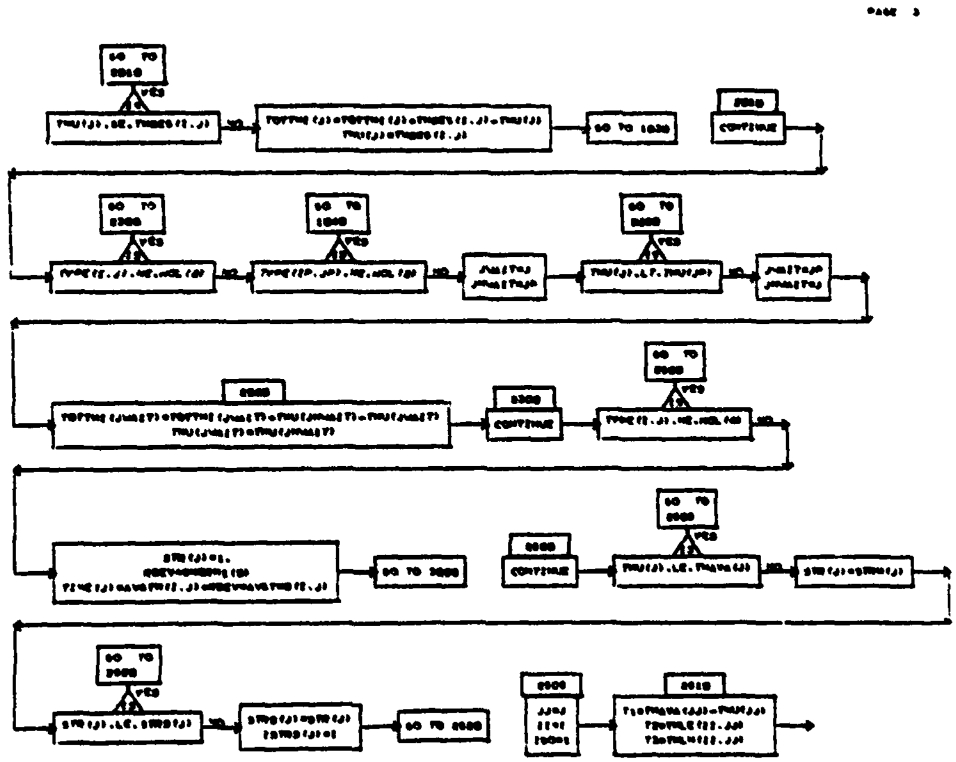

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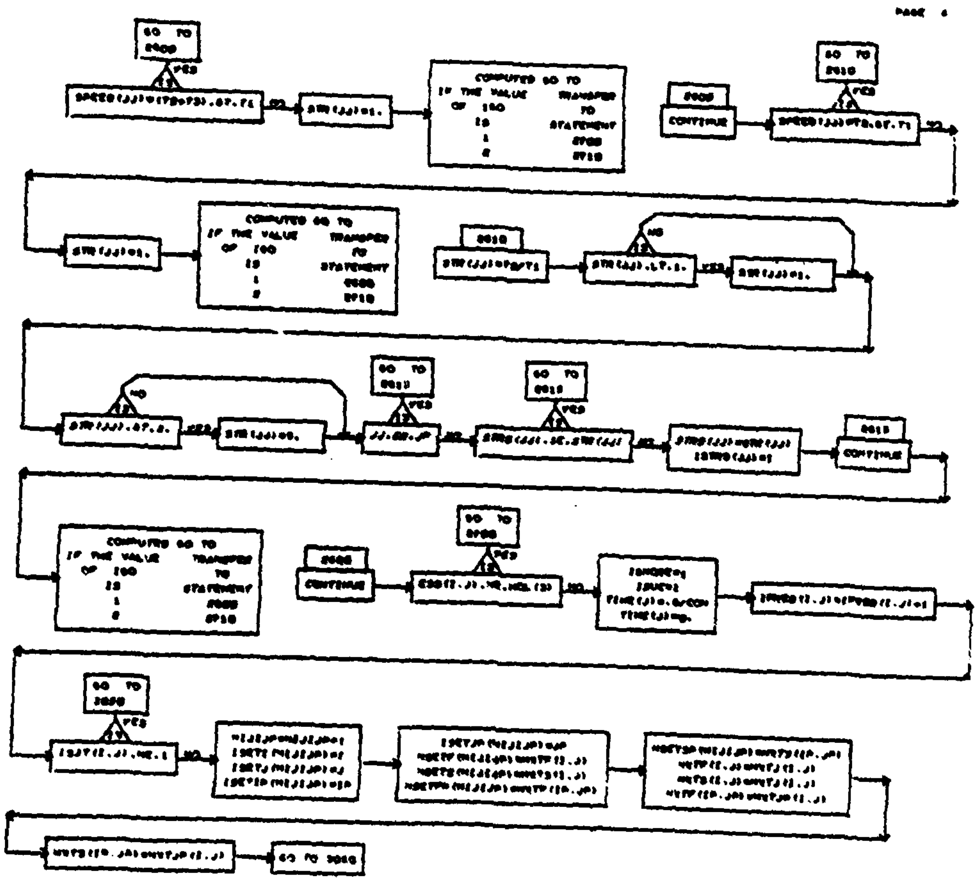

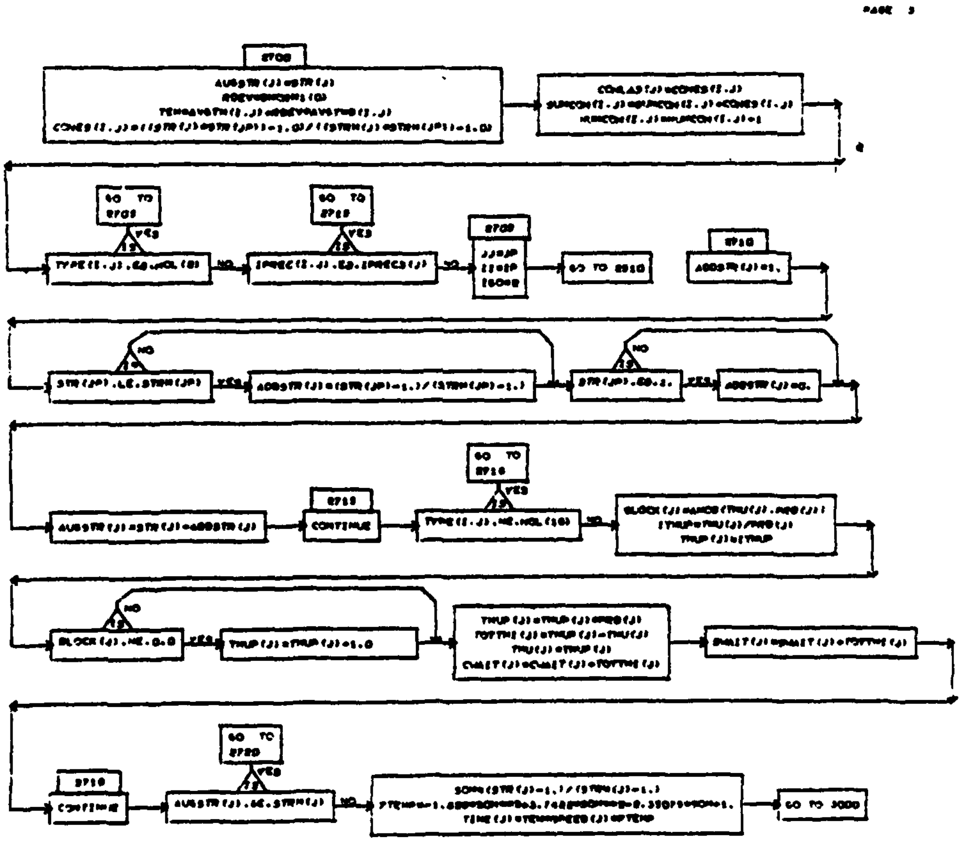

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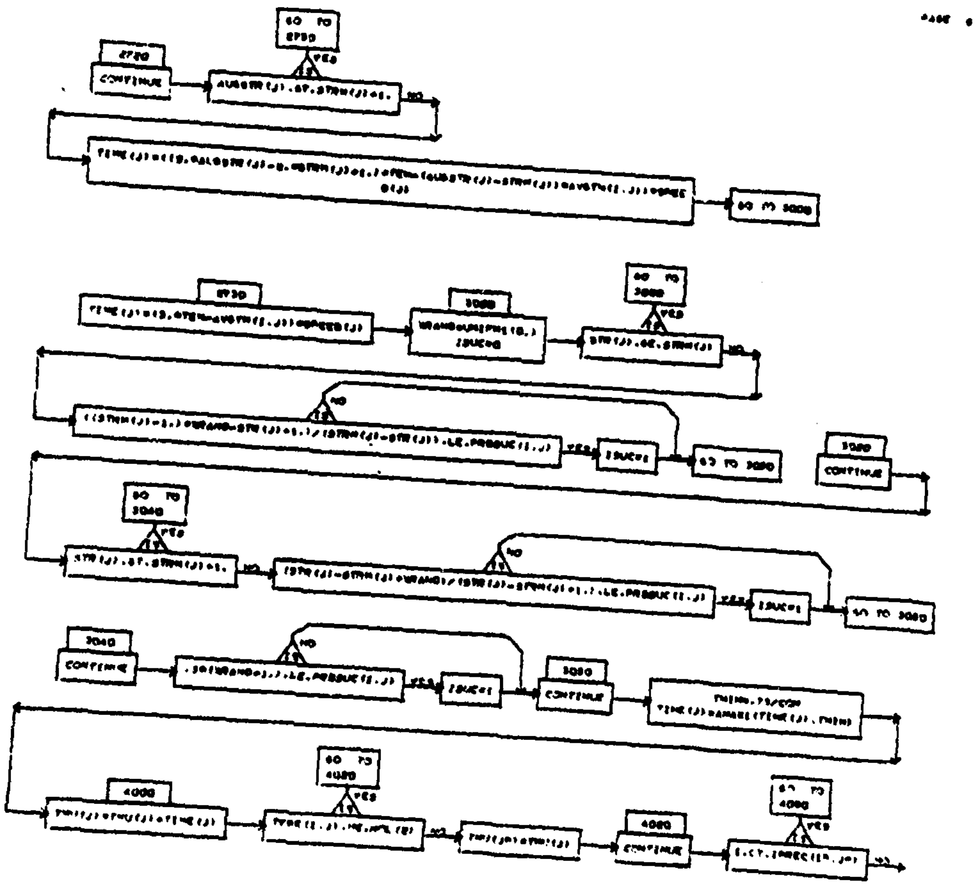
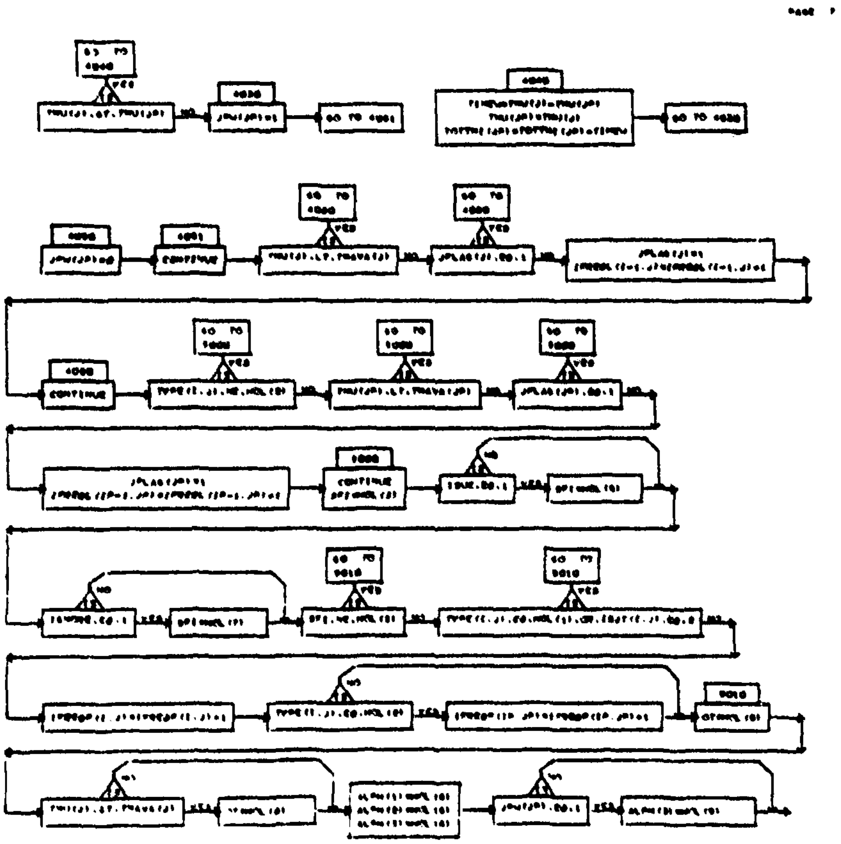
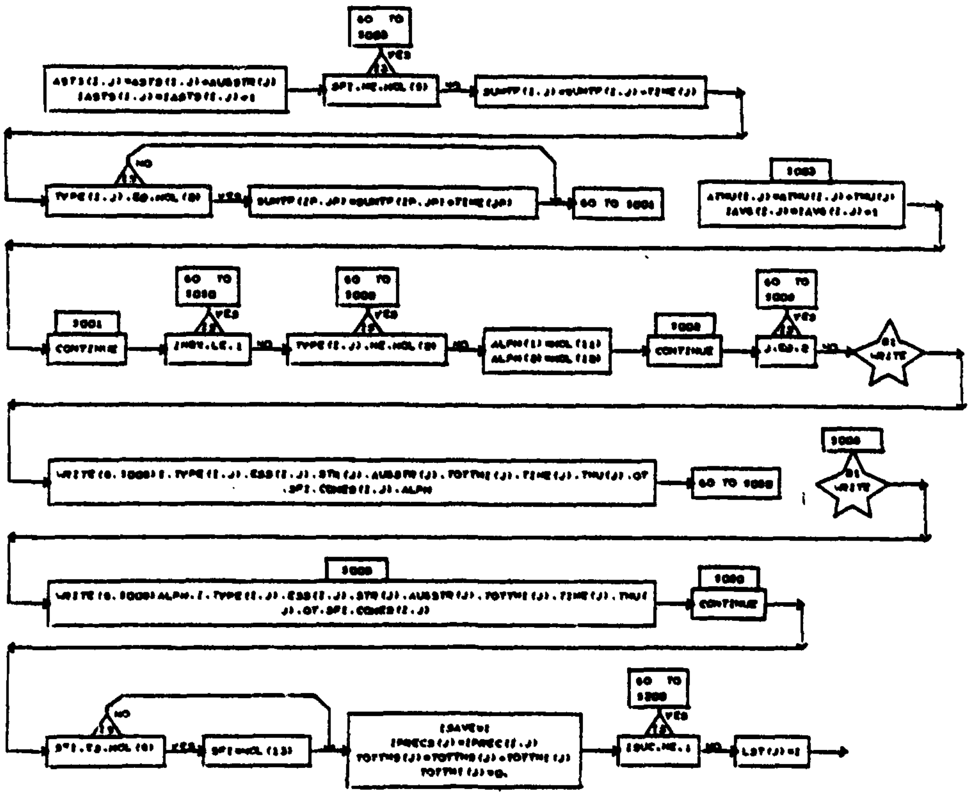
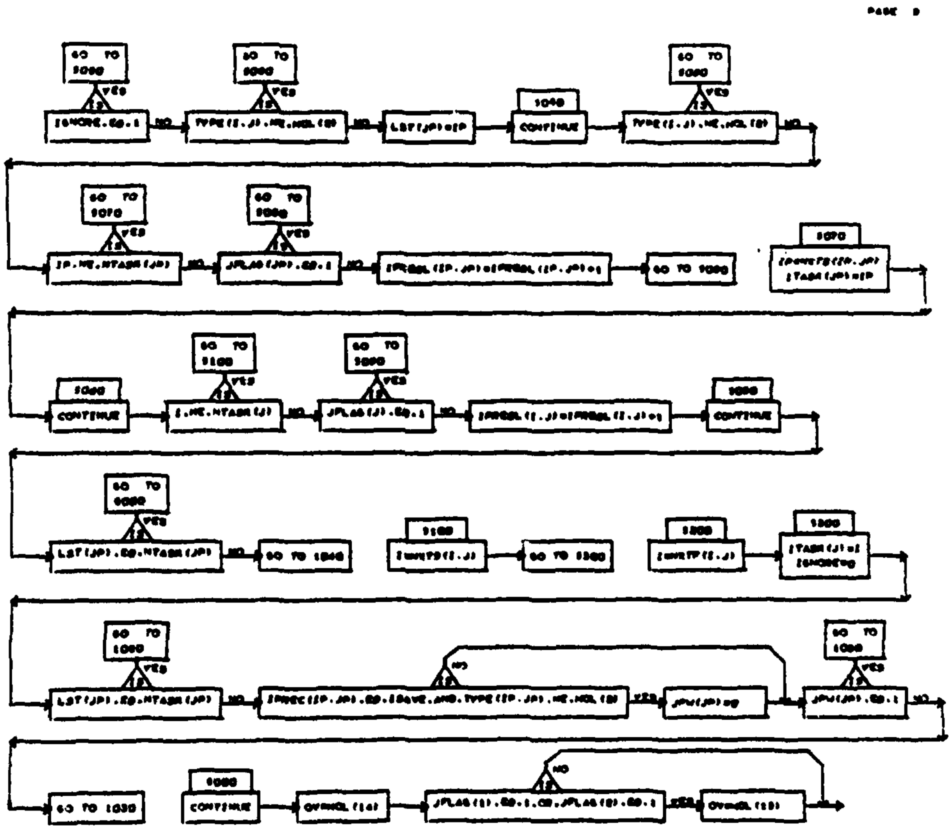





GO TO
YES
NO
CONTINUE
WRITE



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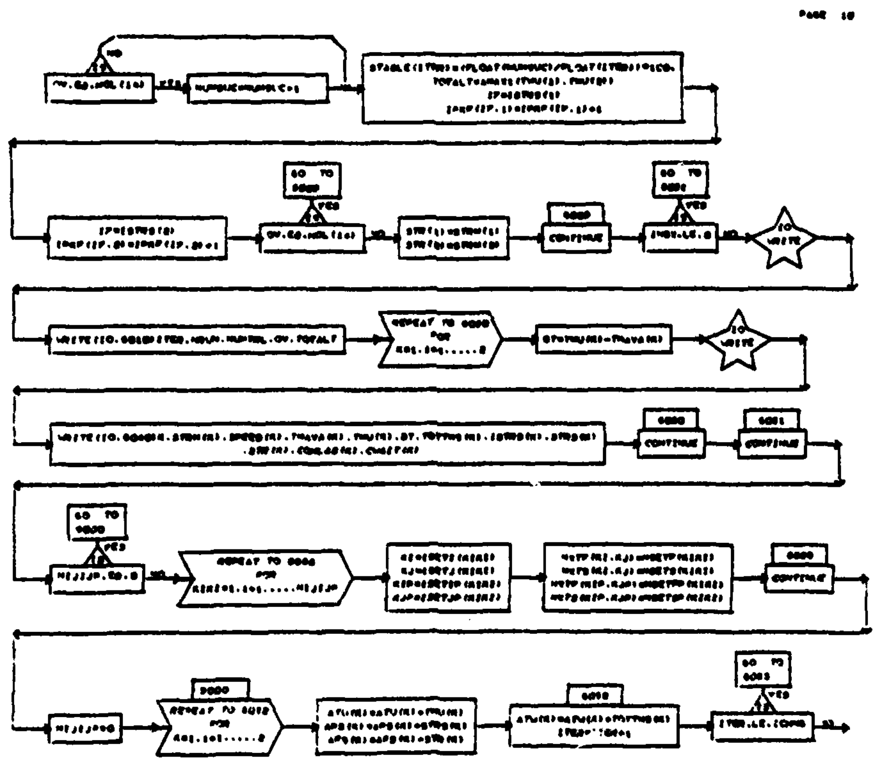

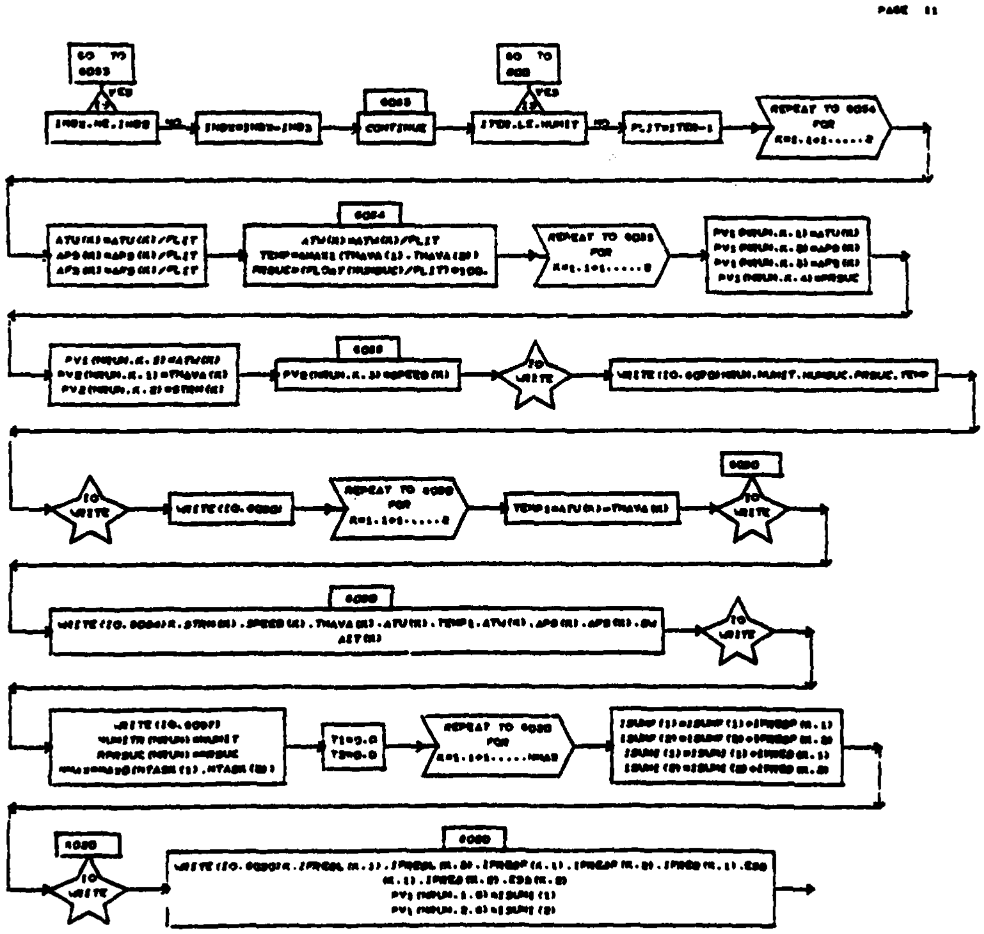

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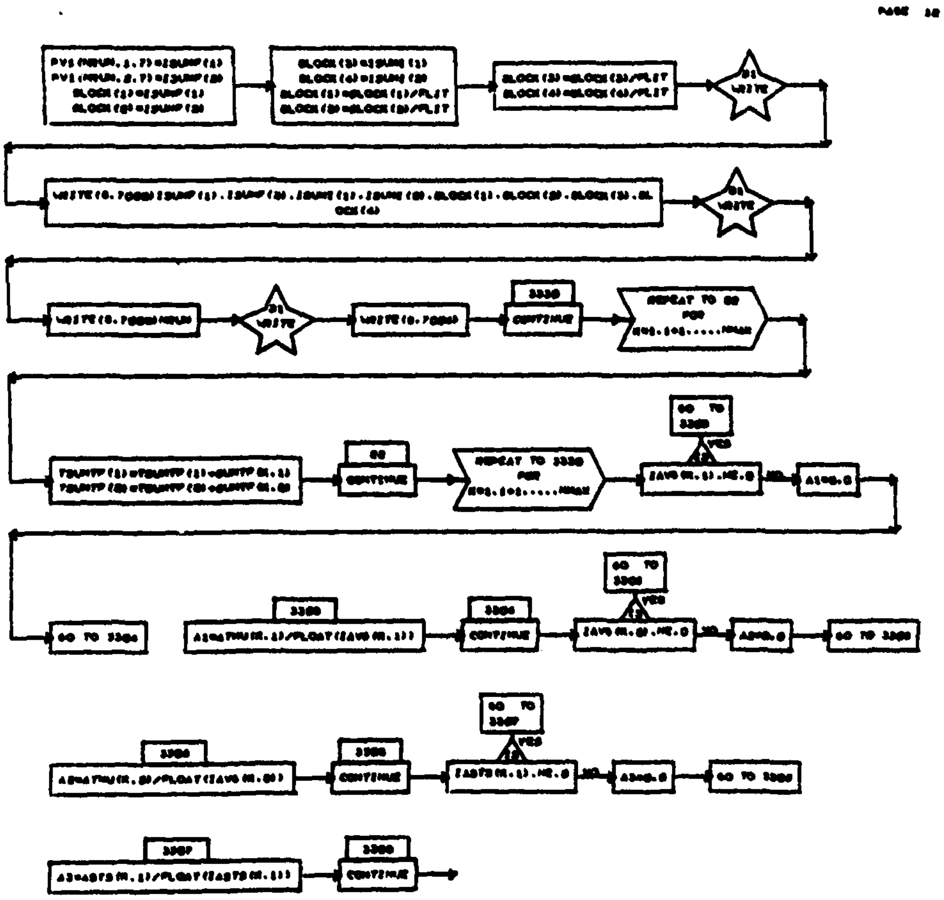
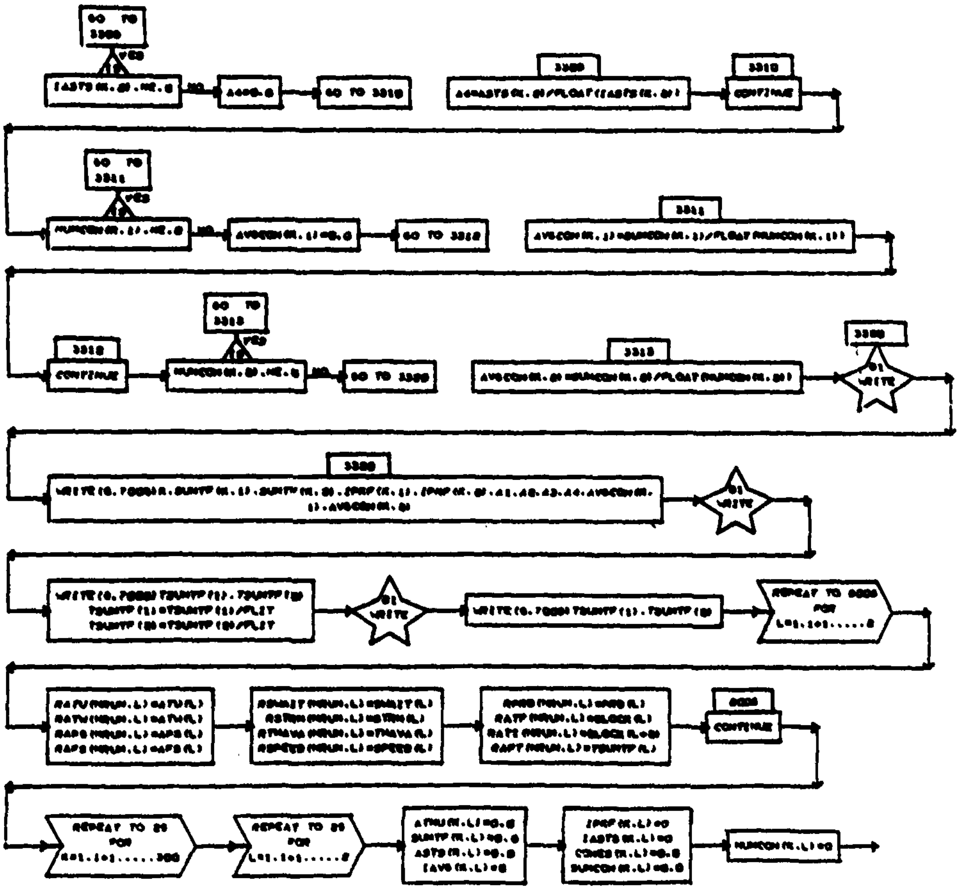
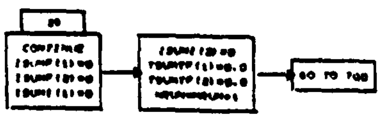
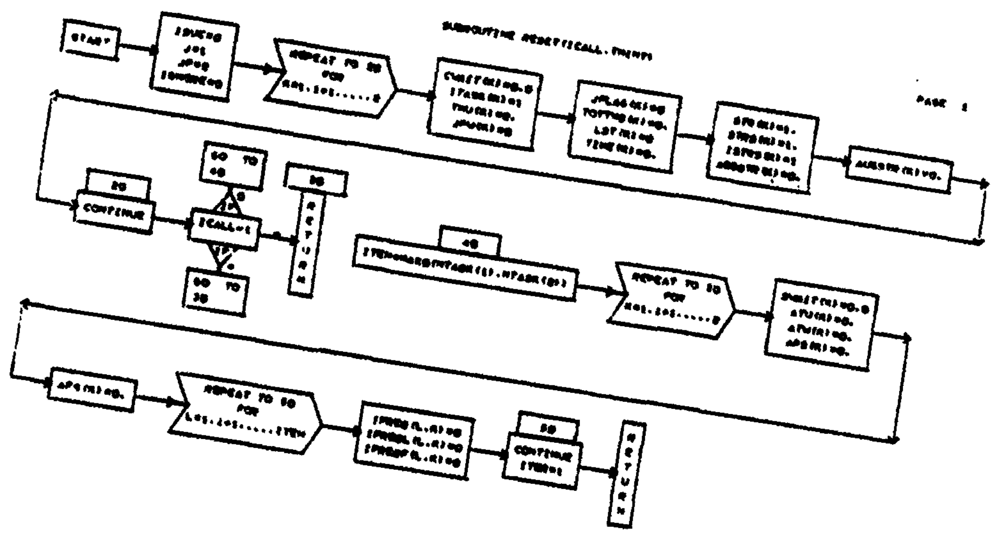
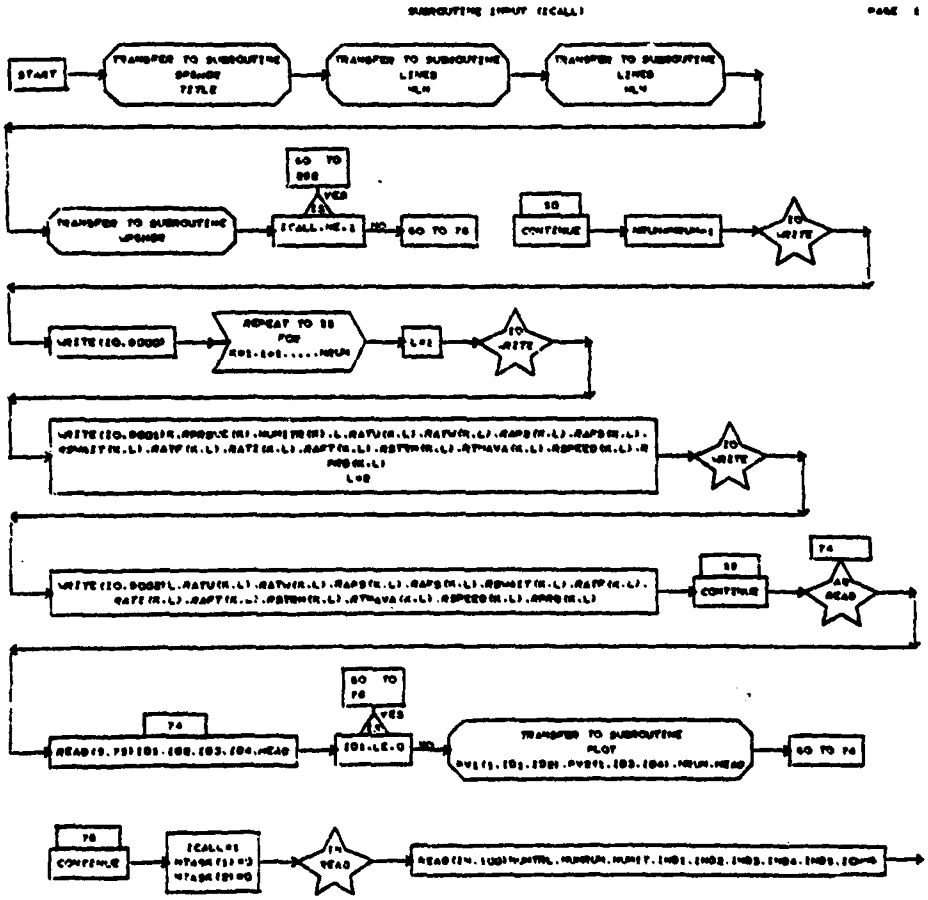







START
REPEAT TO 20
FOR
CONTINUE
GO TO
ICALL=1
RETURN
GO TO
REPEAT TO 50
FOR
CONTINUE
RETURN



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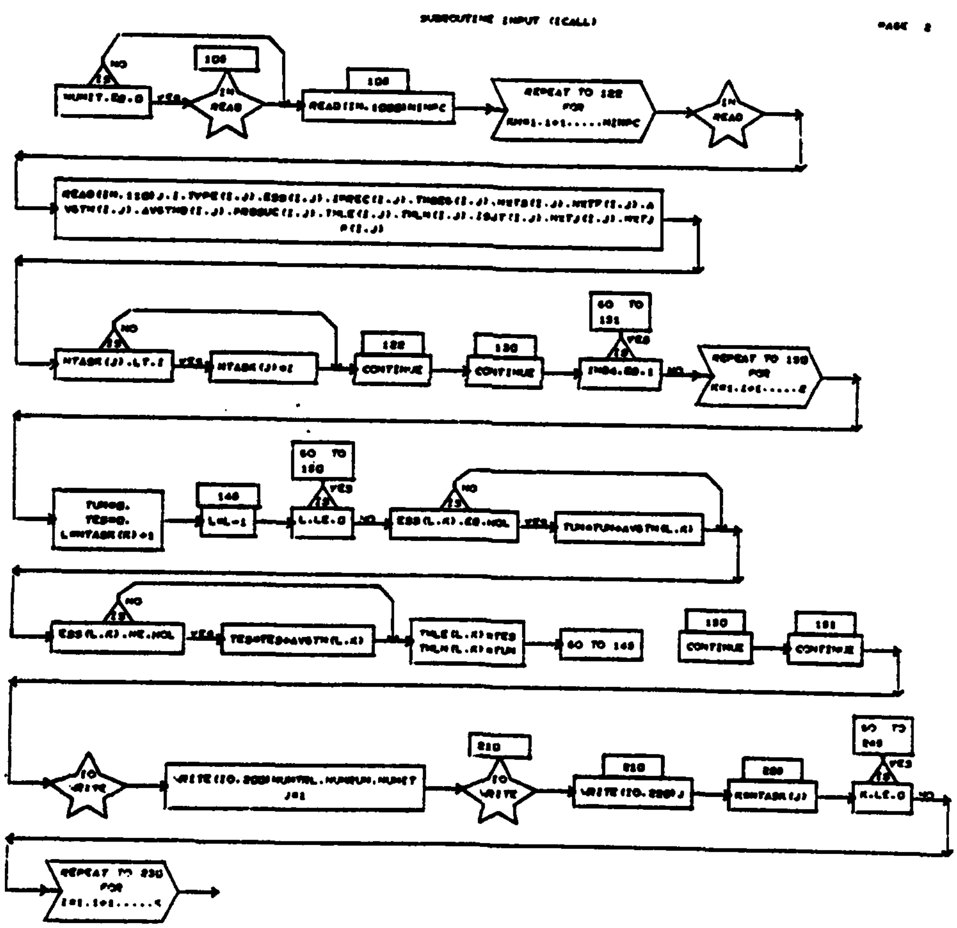

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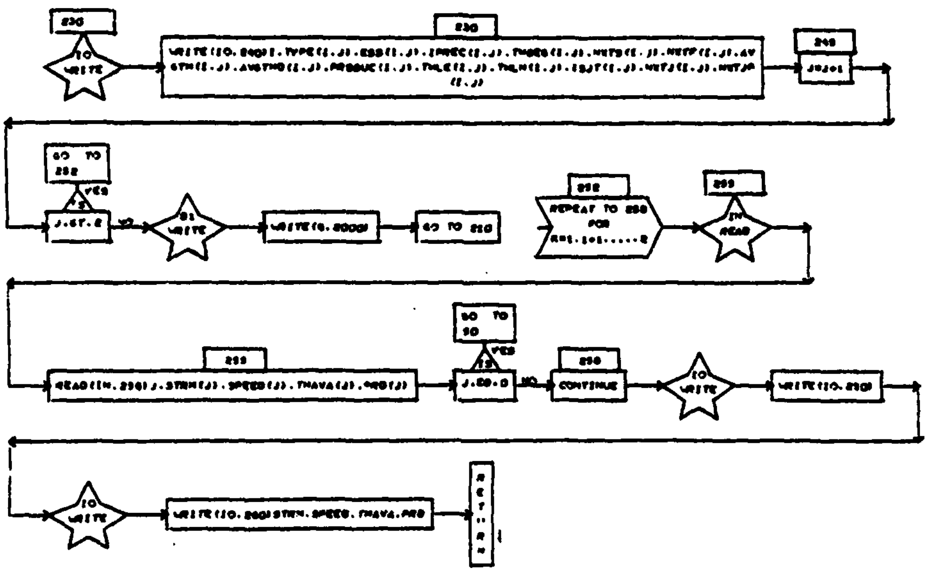

D I M E N S I O N E D   V A R I A B L E S

SYMBOL	STORAGES	SYMBOL	STORAGES	SYMBOL	STORAGES	SYMBOL	STORAGES	SYMBOL	STORAGES
[illegible]	1	[illegible]	[illegible]	N	1	IL	300	PT	100
IP	300	SX	2.2						

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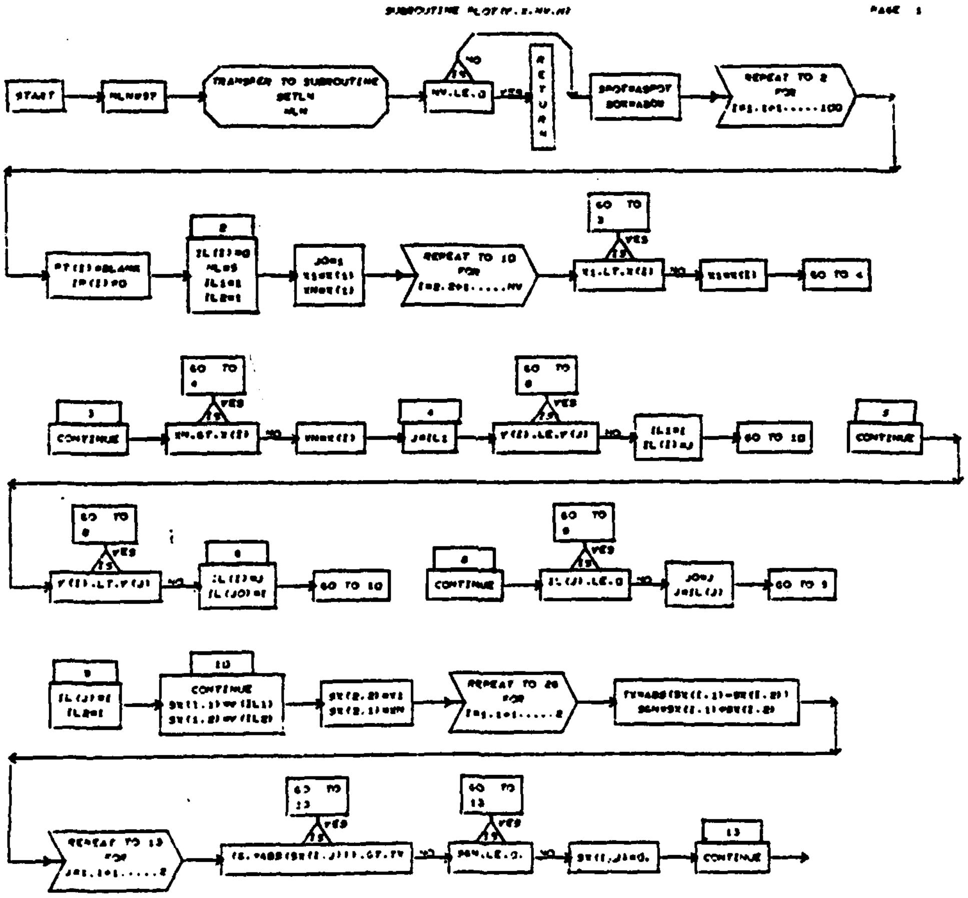
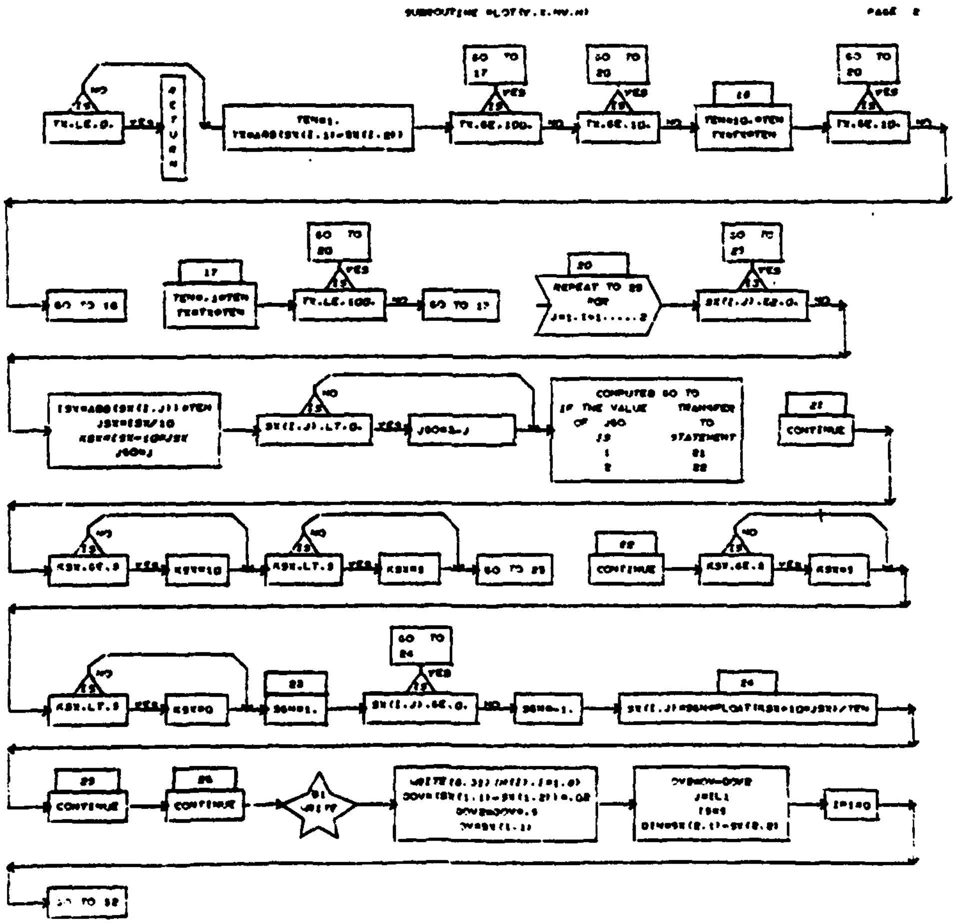
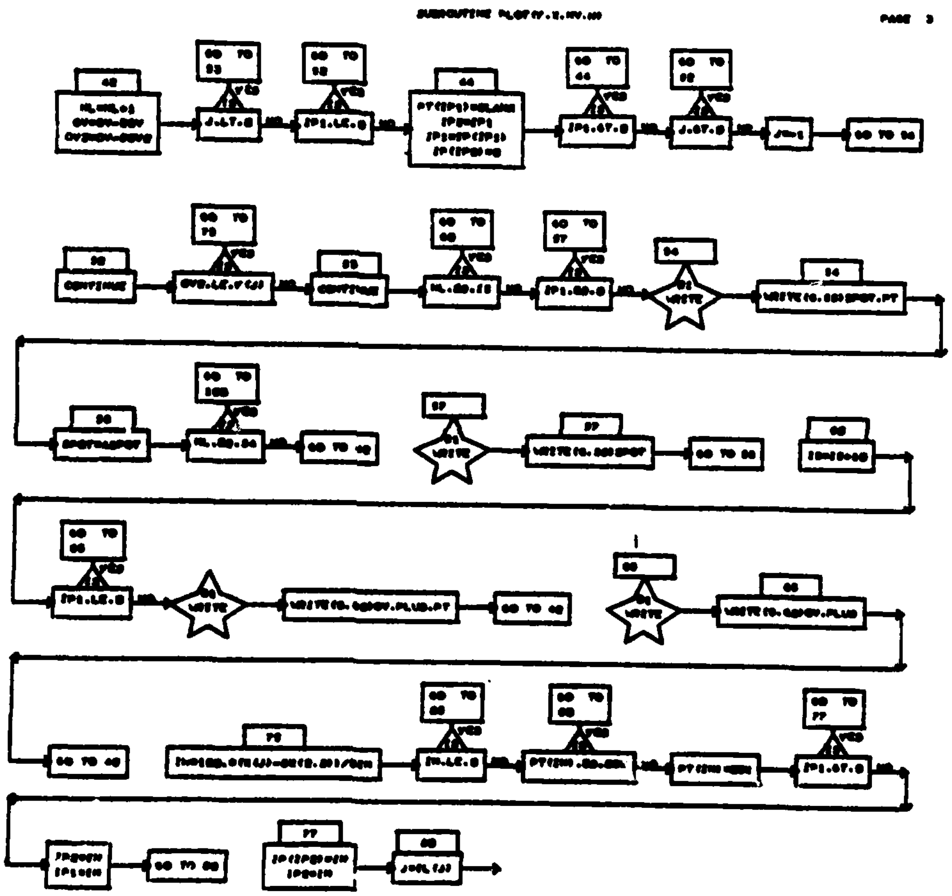



GO TO
YES
NO
CONTINUE
COMPUTED GO TO
IF THE VALUE OF JGO
TRANSFER TO STATEMENT



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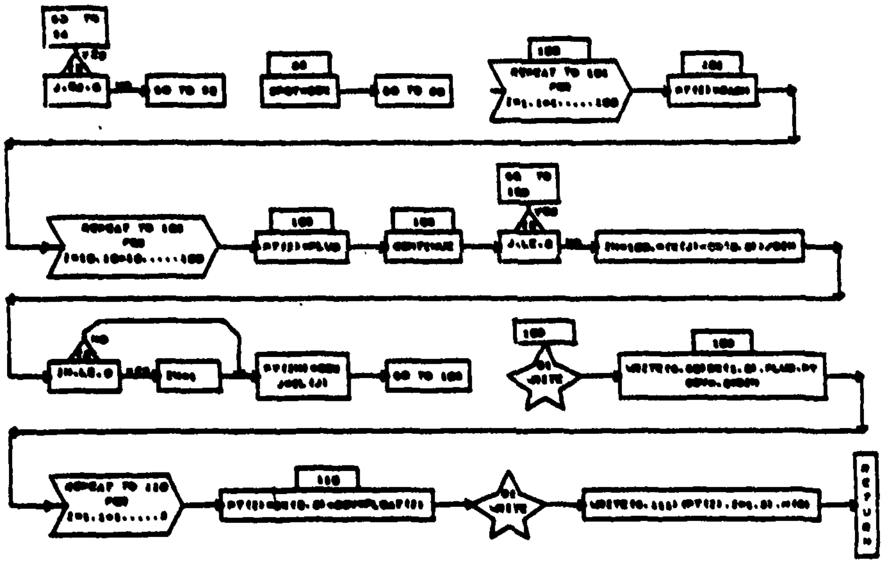
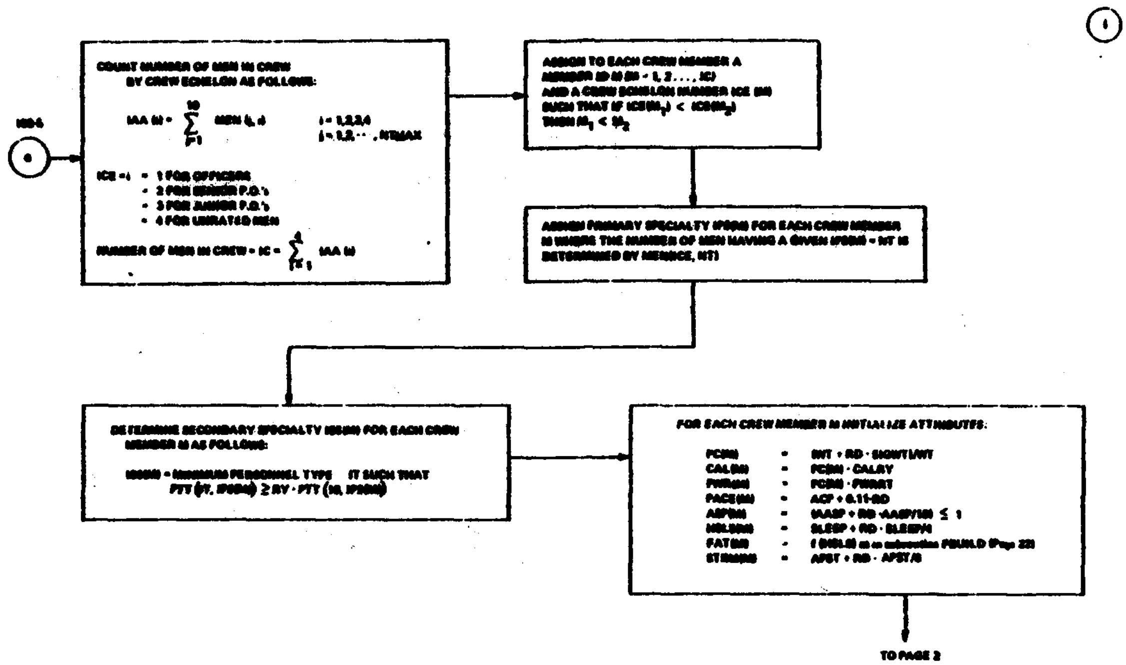
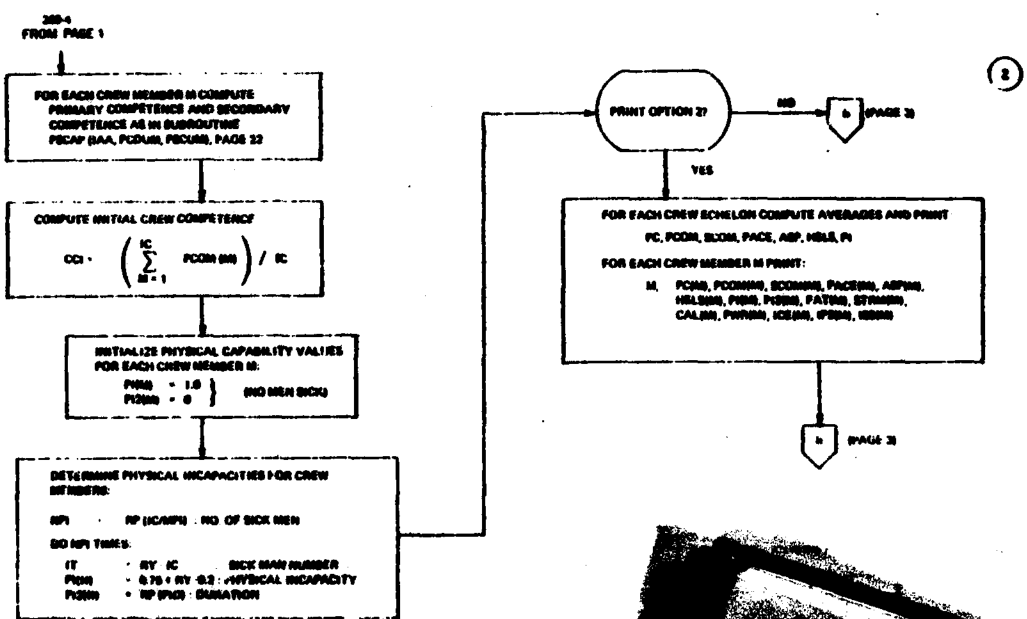
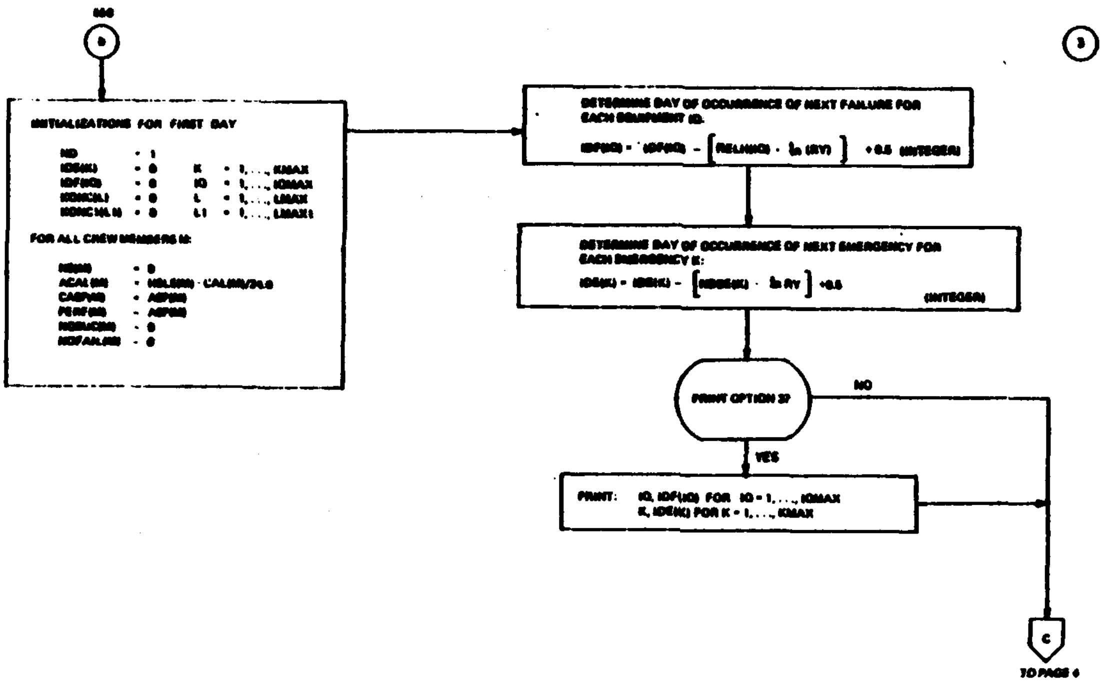
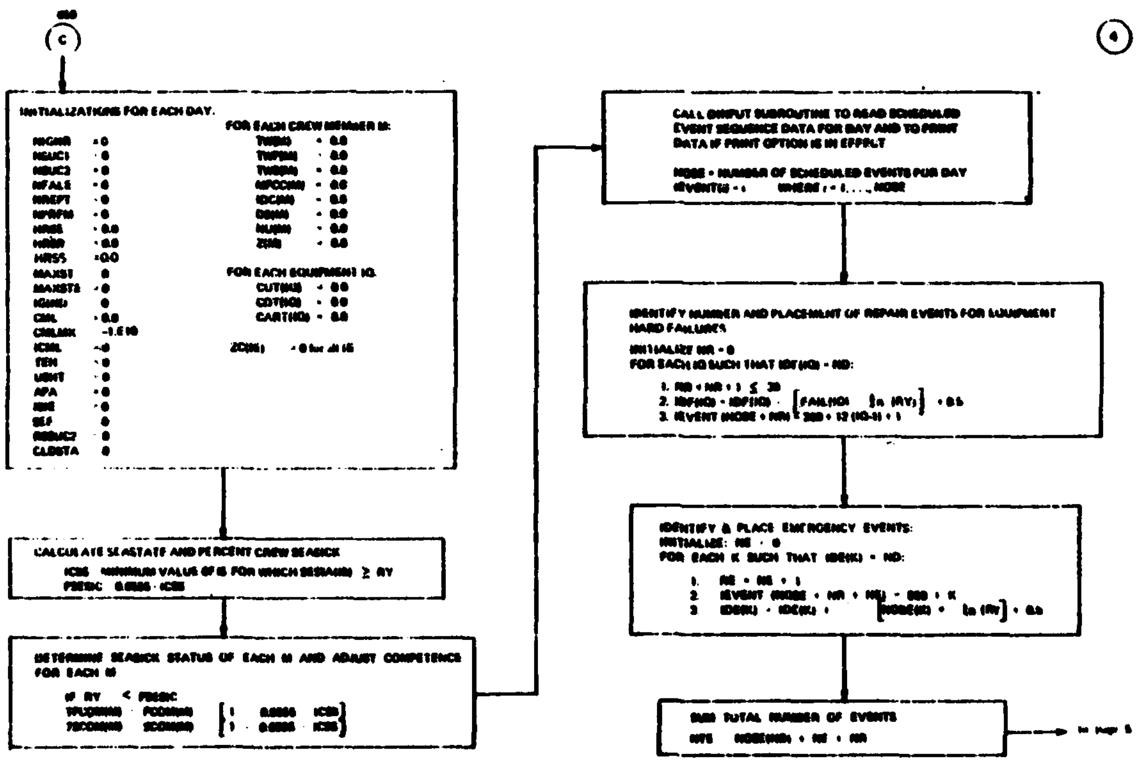


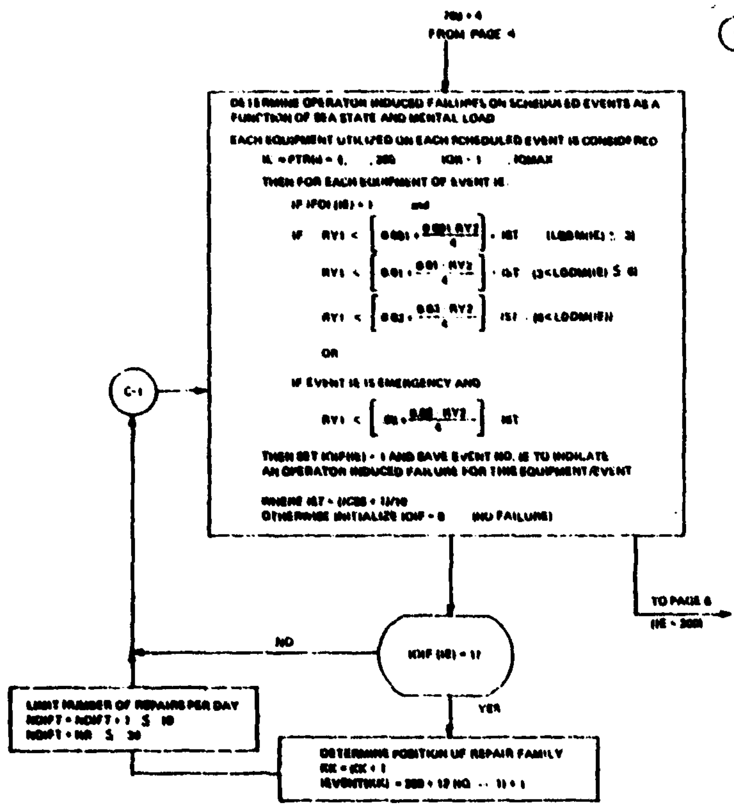
APPENDIX C2 - PROGRAM FLOWCHART

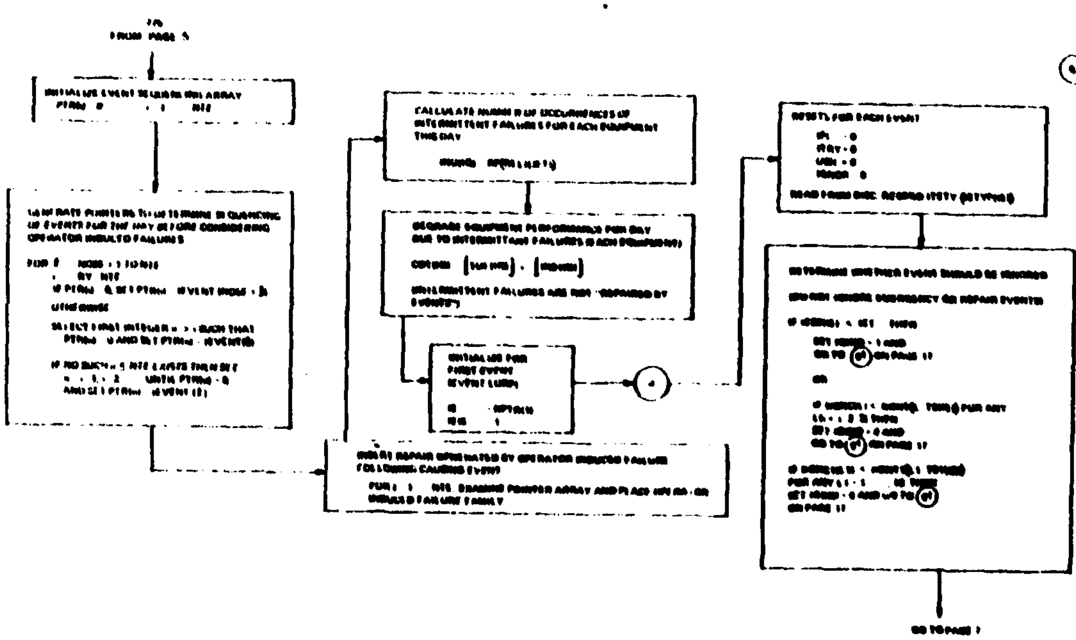

1
COUNT NUMBER OF MEN IN CREW
BY CREW ECHELON AS FOLLOWS:
ICE = 1 FOR OFFICERS
2 FOR SENIOR P.O.'s
3 FOR JUNIOR P.O.'s
4 FOR UNRATED MEN
NUMBER OF MEN IN CREW = IC
ASSIGN TO EACH CREW MEMBER A
AND A CREW ECHELON NUMBER ICE
ASSIGN PRIMARY SPECIALTY FOR EACH CREW MEMBER
DETERMINE SECONDARY SPECIALTY FOR EACH CREW
MEMBER M AS FOLLOWS:
MINIMUM PERSONNEL TYPE IT SUCH THAT
FOR EACH CREW MEMBER M INITIALIZE ATTRIBUTES:
TO PAGE 2

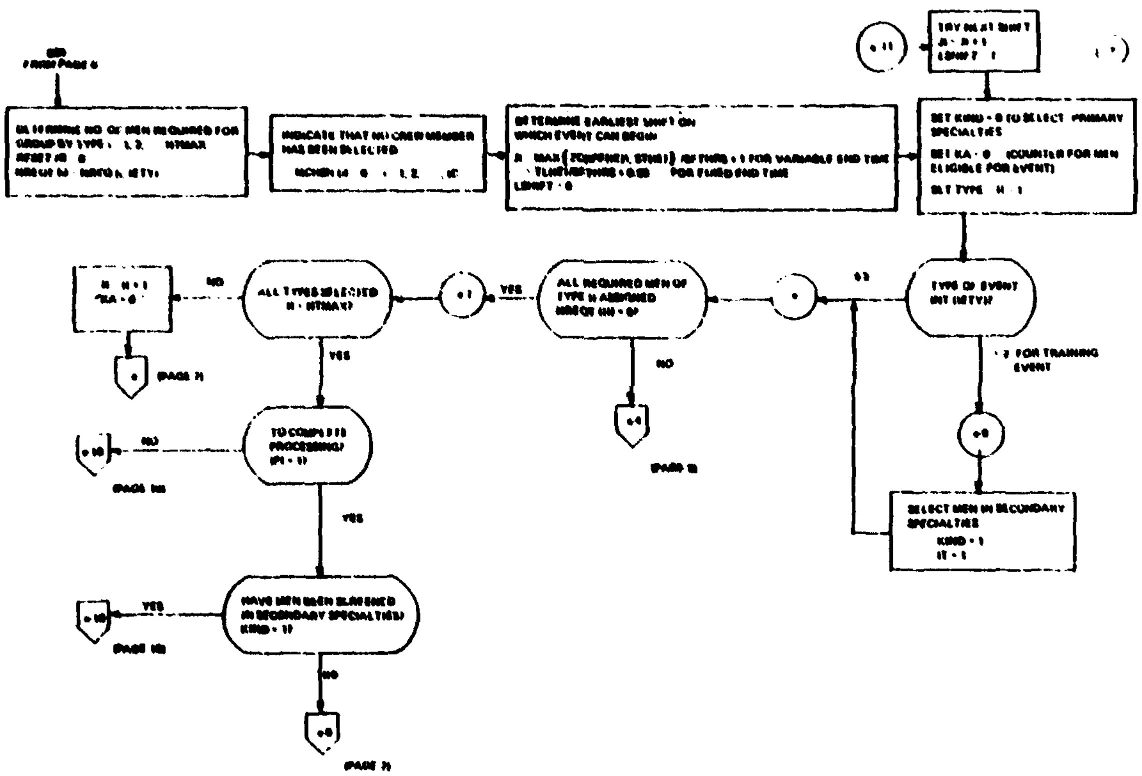

FROM PAGE 1
2
FOR EACH CREW MEMBER M COMPUTE
PRIMARY COMPETENCE AND SECONDARY
COMPETENCE AS IN SUBROUTINE
COMPUTE INITIAL CREW COMPETENCE
INITIALIZE PHYSICAL CAPABILITY VALUES
FOR EACH CREW MEMBER M:
(NO MEN SICK)
DETERMINE PHYSICAL INCAPACITIES FOR CREW
MEMBERS:
NO. OF SICK MEN
SICK MAN NUMBER
PHYSICAL INCAPACITY
DURATION
PRINT OPTION 2?
NO
YES
(PAGE 3)
FOR EACH CREW ECHELON COMPUTE AVERAGES AND PRINT
FOR EACH CREW MEMBER M PRINT:
(PAGE 3)

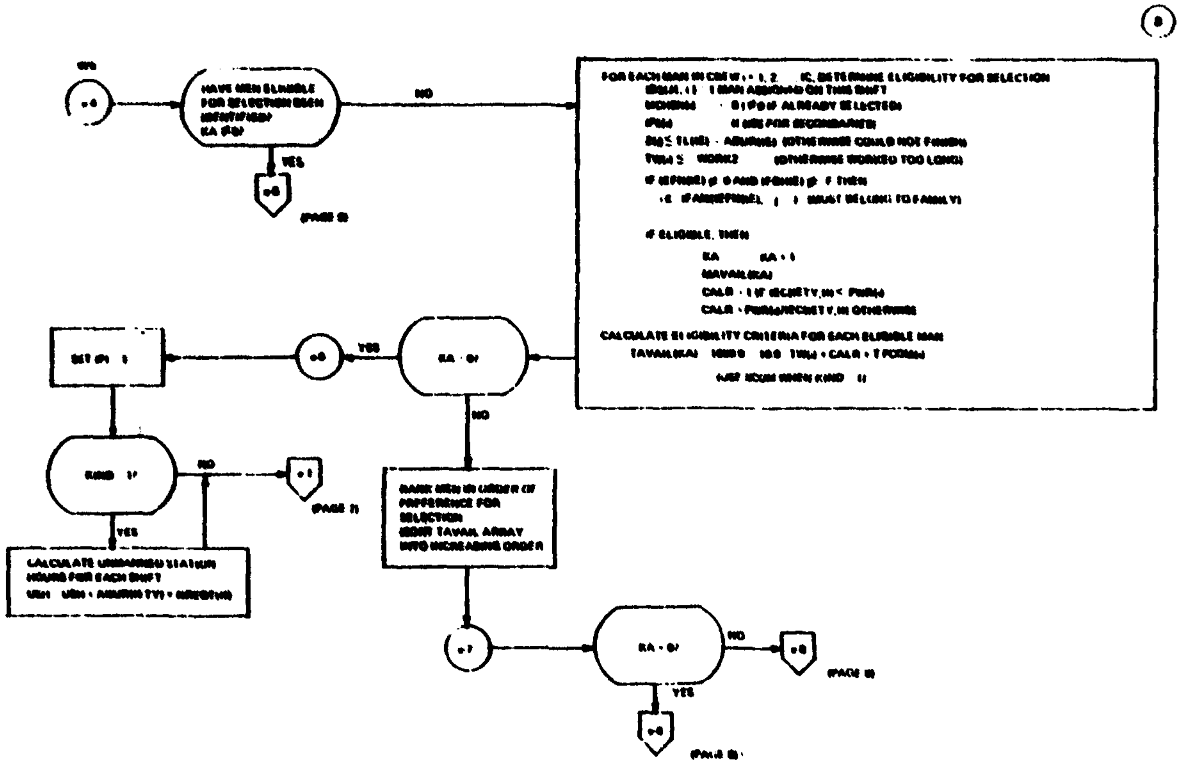

3
INITIALIZATIONS FOR FIRST DAY
FOR ALL CREW MEMBERS M:
DETERMINE DAY OF OCCURRENCE OF NEXT FAILURE FOR EACH EQUIPMENT IQ.
(INTEGER)
DETERMINE DAY OF OCCURRENCE OF NEXT EMERGENCY FOR EACH EMERGENCY K:
(INTEGER)
PRINT OPTION 3?
NO
YES
PRINT: IQ, IDF(IQ) FOR IQ = 1, . . ., IQMAX
K, IDE(K) FOR K = 1, . . ., KMAX
C
TO PAGE 4

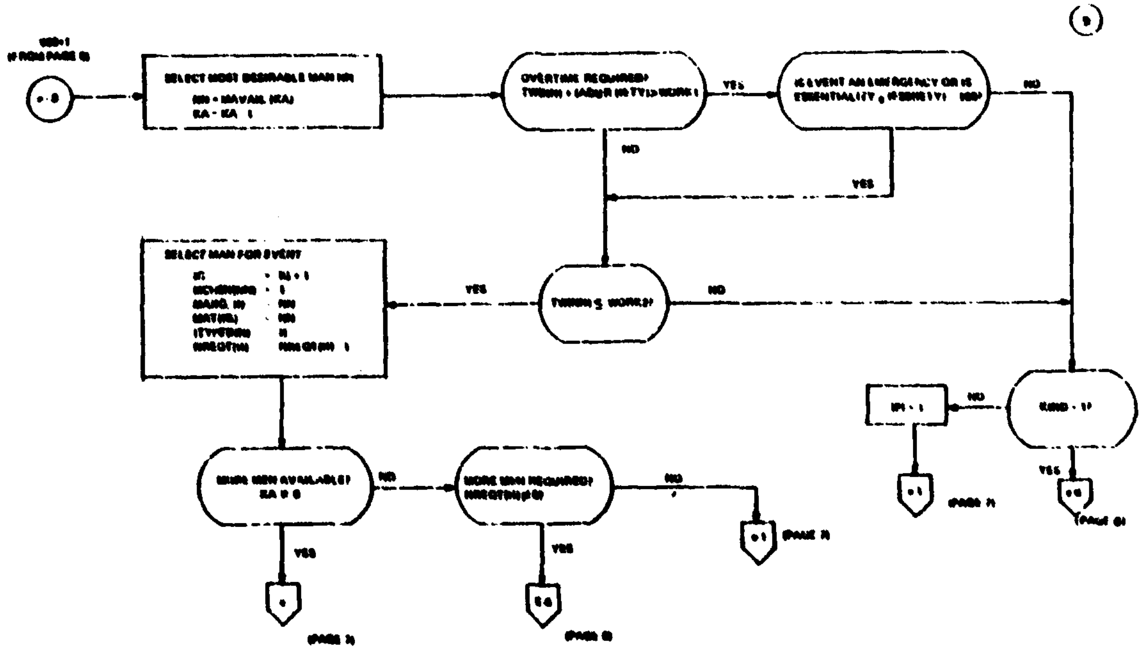

C
4
INITIALIZATIONS FOR EACH DAY.
FOR EACH CREW MEMBER M:
HRSS =0.0
FOR EACH EQUIPMENT IQ.
CALCULATE SEASTATE AND PERCENT CREW SEASICK
DETERMINE SEASICK STATUS OF EACH M AND ADJUST COMPETENCE FOR EACH M
CALL EINPUT SUBROUTINE TO READ SCHEDULED EVENT SEQUENCE DATA FOR DAY AND TO PRINT DATA IF PRINT OPTION IS IN EFFECT
IDENTIFY NUMBER AND PLACEMENT OF REPAIR EVENTS FOR EQUIPMENT HARD FAILURES
IDENTIFY & PLACE EMERGENCY EVENTS:
SUM TOTAL NUMBER OF EVENTS

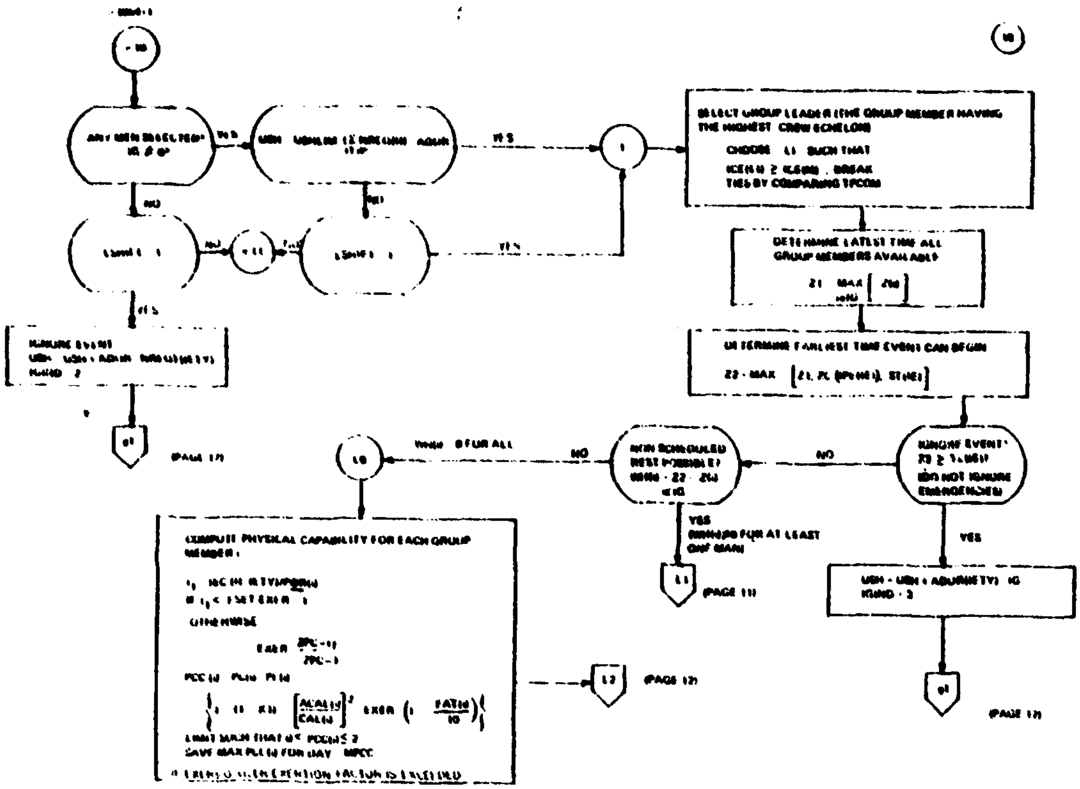

FROM PAGE 4
DETERMINE OPERATOR INDUCED FAILURES ON SCHEDULED EVENTS AS A FUNCTION OF SEA STATE AND MENTAL LOAD
EACH EQUIPMENT UTILIZED ON EACH SCHEDULED EVENT IS CONSIDERED
THEN FOR EACH EQUIPMENT OF EVENT IE
OR
IF EVENT IE IS EMERGENCY AND
OTHERWISE INITIALIZE IOIF = 0 (NO FAILURE)
TO PAGE 6
NO
YES
C-1
LIMIT NUMBER OF REPAIRS PER DAY
DETERMINE POSITION OF REPAIR FAMILY

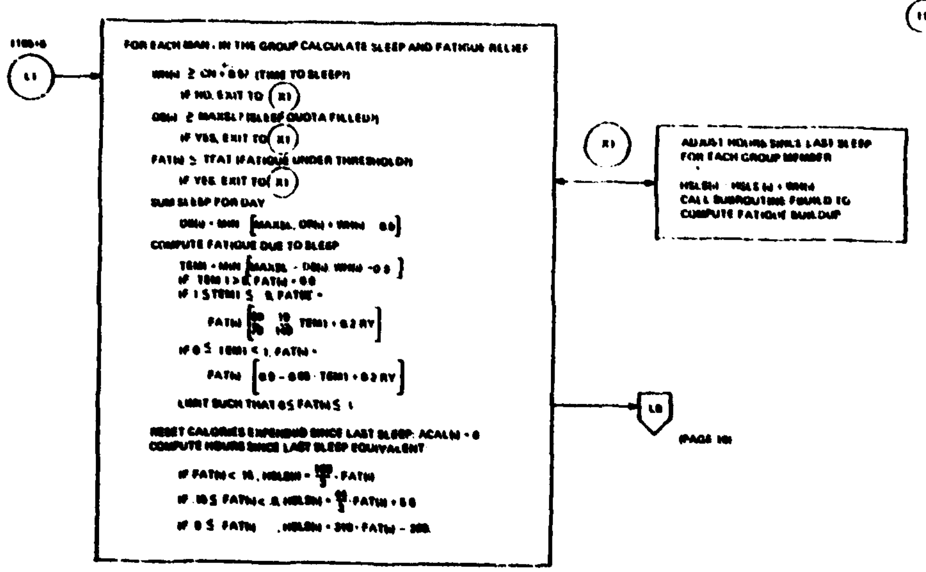

FROM PAGE 5
GO TO PAGE 7


INDICATE THAT NO CREW MEMBER HAS BEEN SELECTED
DETERMINE EARLIEST SHIFT ON WHICH EVENT CAN BEGIN
TRY NEXT SHIFT
SET KIND = 0 TO SELECT PRIMARY SPECIALTIES
ALL TYPES SELECTED
ALL REQUIRED MEN OF TYPE N ASSIGNED
TYPE OF EVENT
FOR TRAINING EVENT
YES
NO
TO COMPLETE PROCESSING
SELECT MEN IN SECONDARY SPECIALTIES
HAVE MEN BEEN ASSIGNED IN SECONDARY SPECIALTIES


NO
YES
RANK MEN IN ORDER OF PREFERENCE FOR SELECTION
(SORT TAVAIL ARRAY INTO INCREASING ORDER)
CALCULATE ELIGIBILITY CRITERIA FOR EACH ELIGIBLE MAN


SELECT MOST DESIRABLE MAN
OVERTIME REQUIRED?
SELECT MAN FOR EVENT
MORE MEN REQUIRED?
NO
YES


YES
NO
SELECT GROUP LEADER (THE GROUP MEMBER HAVING THE HIGHEST CREW ECHELON)
DETERMINE LATEST TIME ALL GROUP MEMBERS AVAILABLE
DETERMINE EARLIEST TIME EVENT CAN BEGIN
COMPUTE PHYSICAL CAPABILITY FOR EACH GROUP MEMBER
OTHERWISE
(PAGE 11)
(PAGE 12)


FOR EACH MAN IN THE GROUP CALCULATE SLEEP AND FATIGUE RELIEF
SUM SLEEP FOR DAY
COMPUTE FATIGUE DUE TO SLEEP
ADJUST HOURS SINCE LAST SLEEP FOR EACH GROUP MEMBER
CALL SUBROUTINE FBUILD TO COMPUTE FATIGUE BUILDUP
(PAGE 10)

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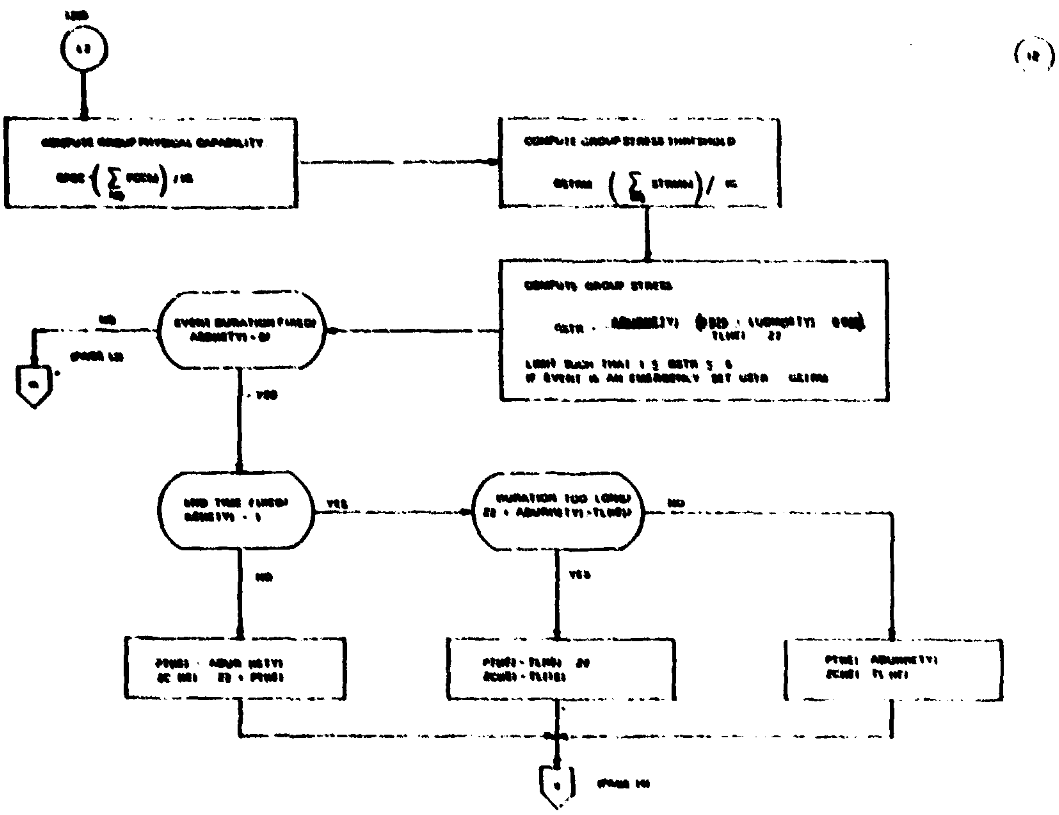
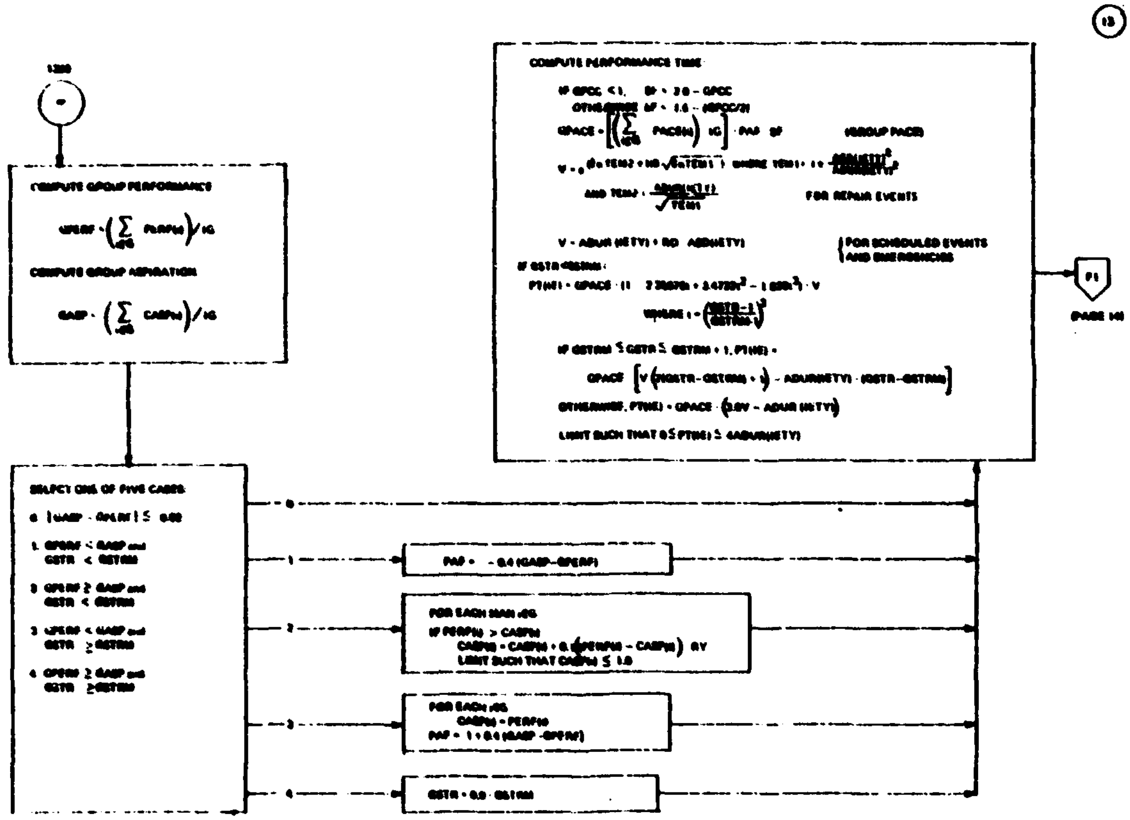
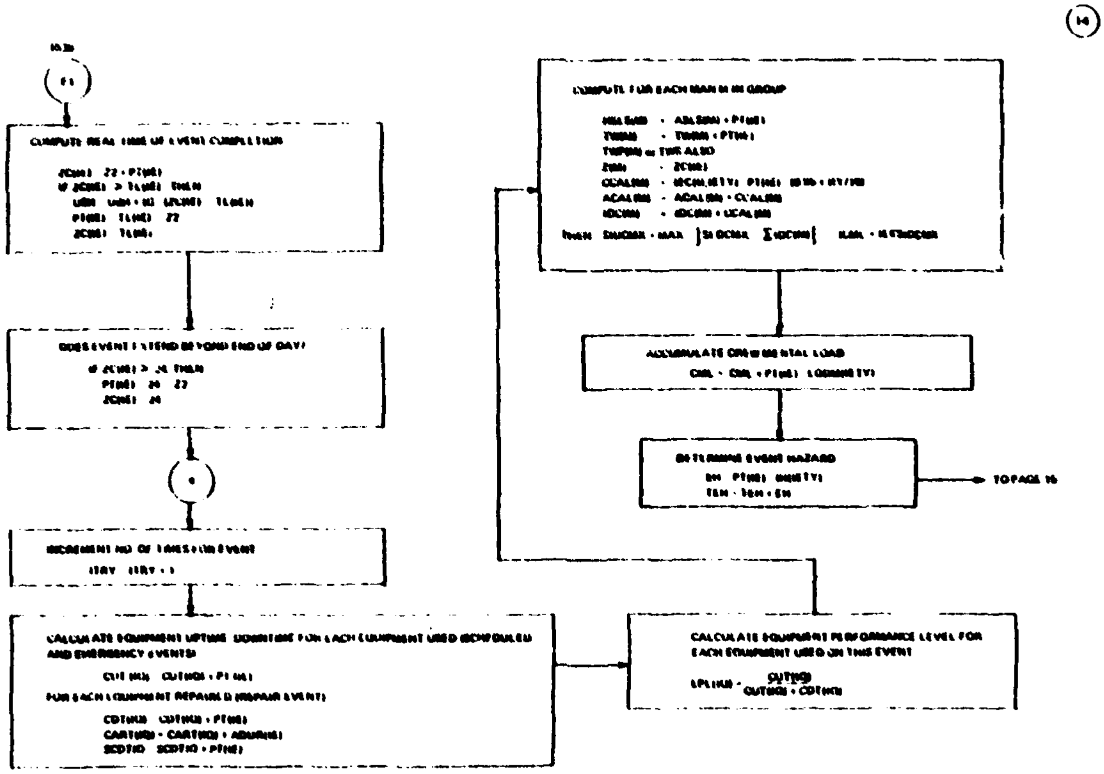
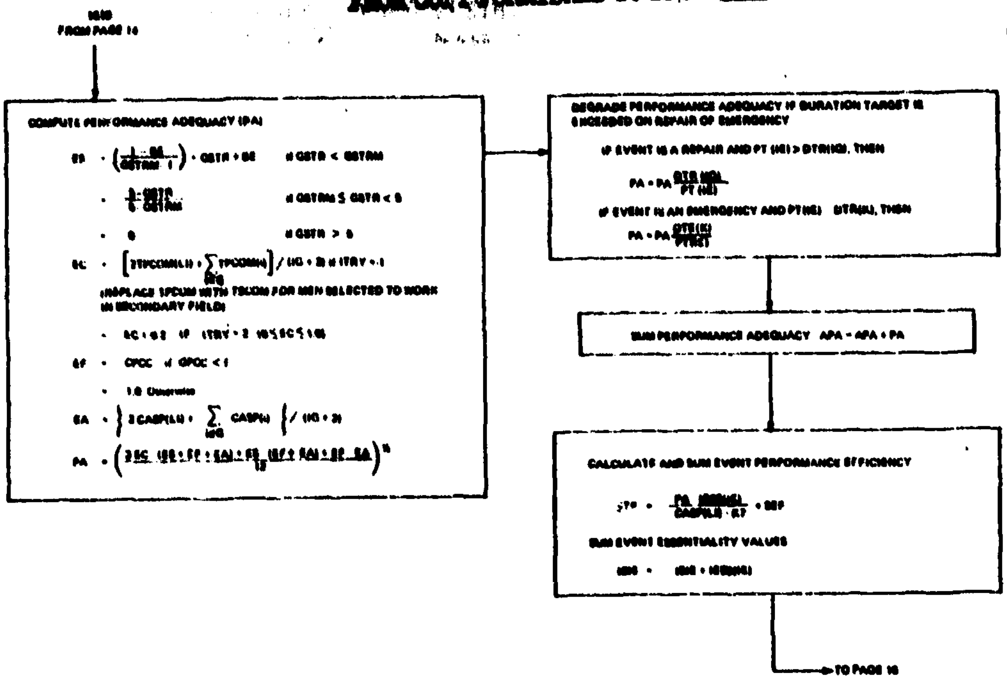
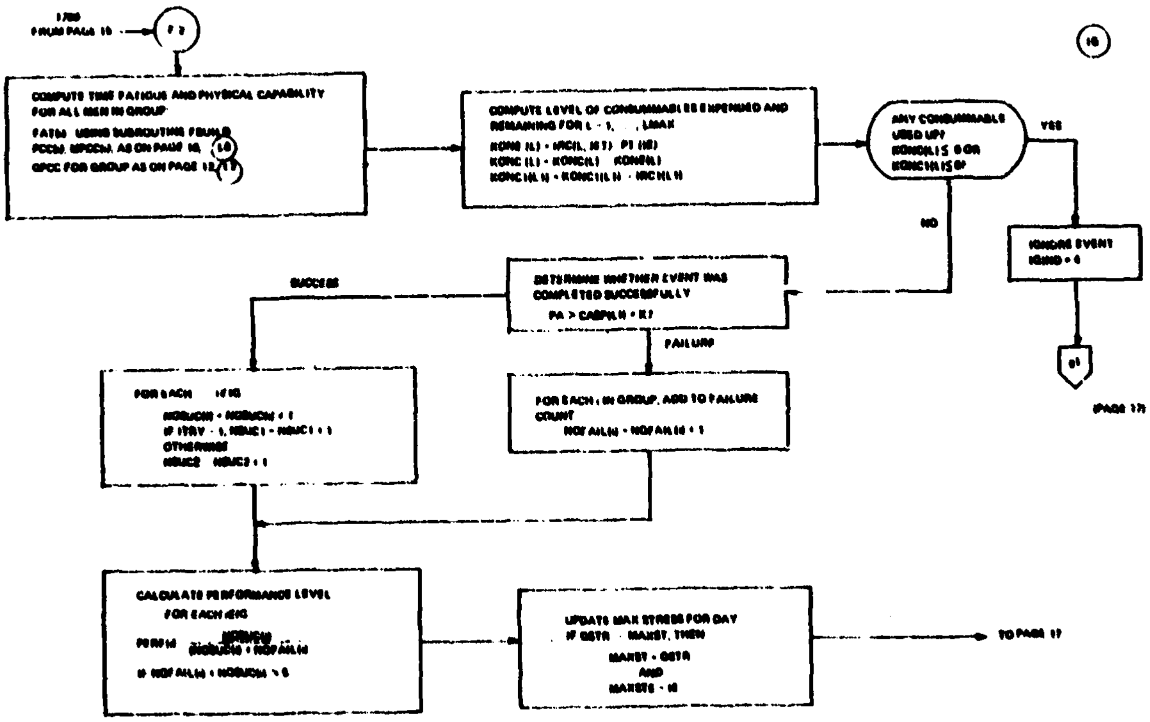
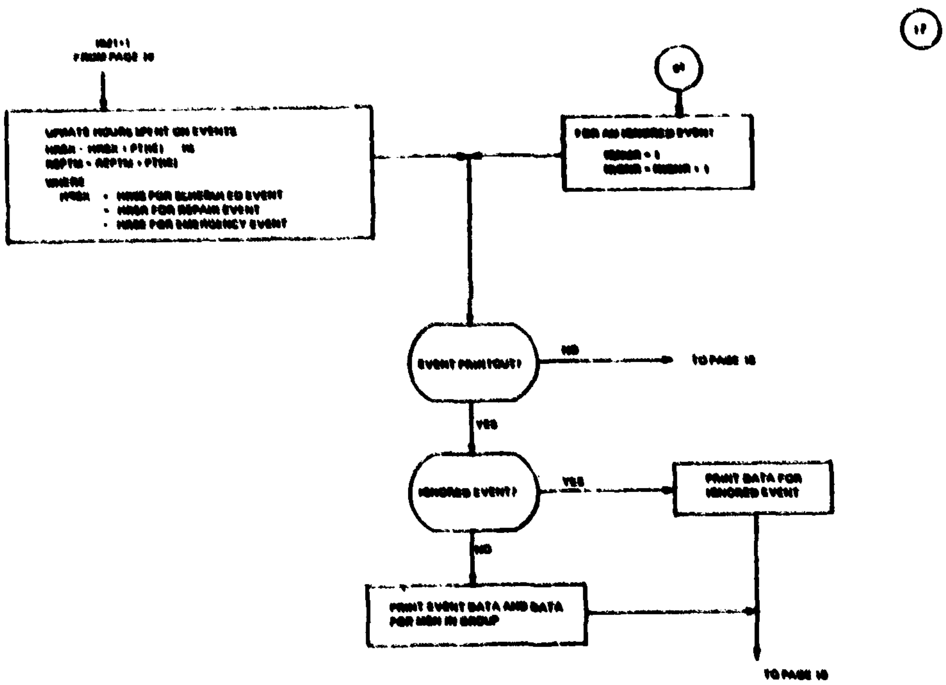



COMPUTE GROUP PERFORMANCE
COMPUTE GROUP ASPIRATION
SELECT ONE OF FIVE CASES
COMPUTE PERFORMANCE TIME
FOR REPAIR EVENTS
FOR SCHEDULED EVENTS AND EMERGENCIES


COMPUTE REAL TIME OF EVENT COMPLETION
DOES EVENT EXTEND BEYOND END OF DAY?
CALCULATE EQUIPMENT UPTIME DOWNTIME FOR EACH EQUIPMENT USED (SCHEDULED AND EMERGENCY EVENTS)
FOR EACH EQUIPMENT REPAIRED (REPAIR EVENT)
CALCULATE EQUIPMENT PERFORMANCE LEVEL FOR EACH EQUIPMENT USED ON THIS EVENT
COMPUTE FOR EACH MAN M IN GROUP
ACCUMULATE ENVIRONMENTAL LOAD
DETERMINE EVENT HAZARD
TO PAGE 16


FROM PAGE 14
COMPUTE PERFORMANCE ADEQUACY (PA)
DEGRADE PERFORMANCE ADEQUACY IF DURATION TARGET IS EXCEEDED ON REPAIR OF EMERGENCY
IF EVENT IS A REPAIR AND PT (IE) > DTR(IE), THEN
IF EVENT IS AN EMERGENCY AND PT(IE) DTR(IE), THEN
SUM PERFORMANCE ADEQUACY APA = APA + PA
CALCULATE AND SUM EVENT PERFORMANCE EFFICIENCY
SUM EVENT ESSENTIALITY VALUES
TO PAGE 16


FROM PAGE 15
COMPUTE TIME FATIGUE AND PHYSICAL CAPABILITY FOR ALL MEN IN GROUP
COMPUTE LEVEL OF CONSUMMABLES EXPENDED AND REMAINING FOR L = 1, . . . , LMAX
ANY CONSUMMABLE USED UP?
YES
NO
IGNORE EVENT
DETERMINE WHETHER EVENT WAS COMPLETED SUCCESSFULLY
SUCCESS
FAILURE
FOR EACH
OTHERWISE
FOR EACH i IN GROUP, ADD TO FAILURE COUNT
(PAGE 17)
CALCULATE PERFORMANCE LEVEL FOR EACH
UPDATE MAX STRESS FOR DAY
AND
TO PAGE 17


EVENT PRINTOUT?
NO
YES
IGNORED EVENT?
YES
NO
PRINT DATA FOR IGNORED EVENT
PRINT EVENT DATA AND DATA FOR MEN IN GROUP
FOR AN IGNORED EVENT

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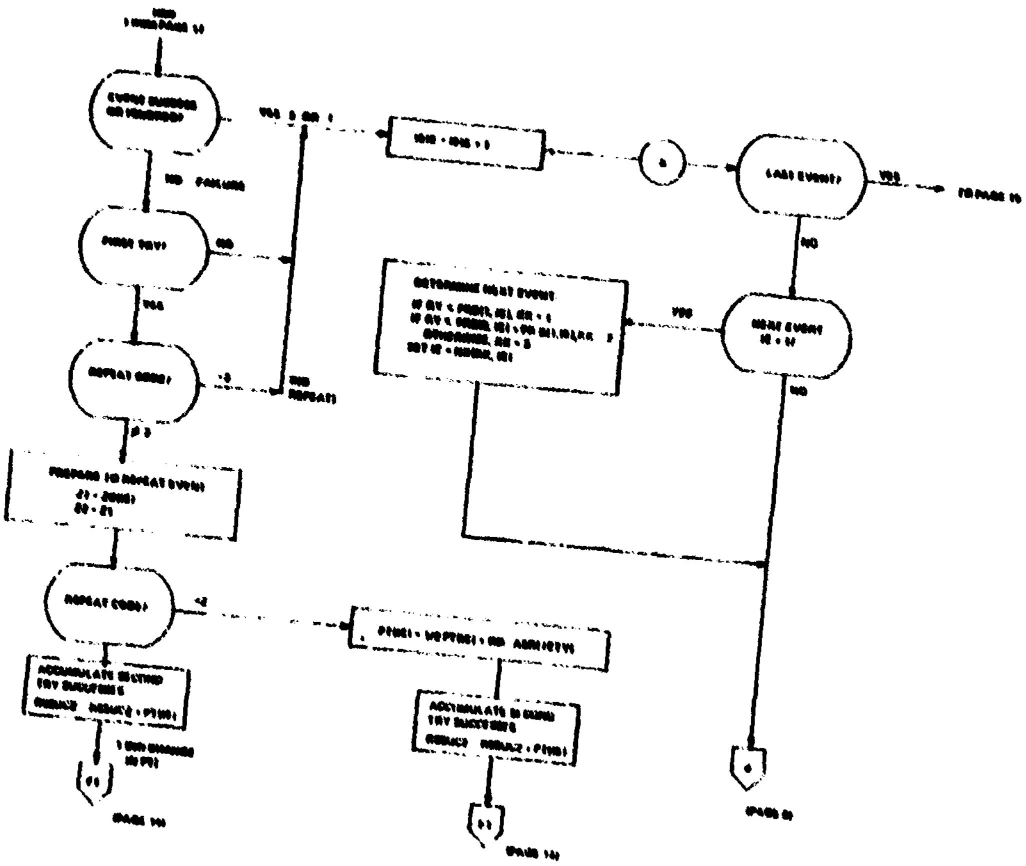
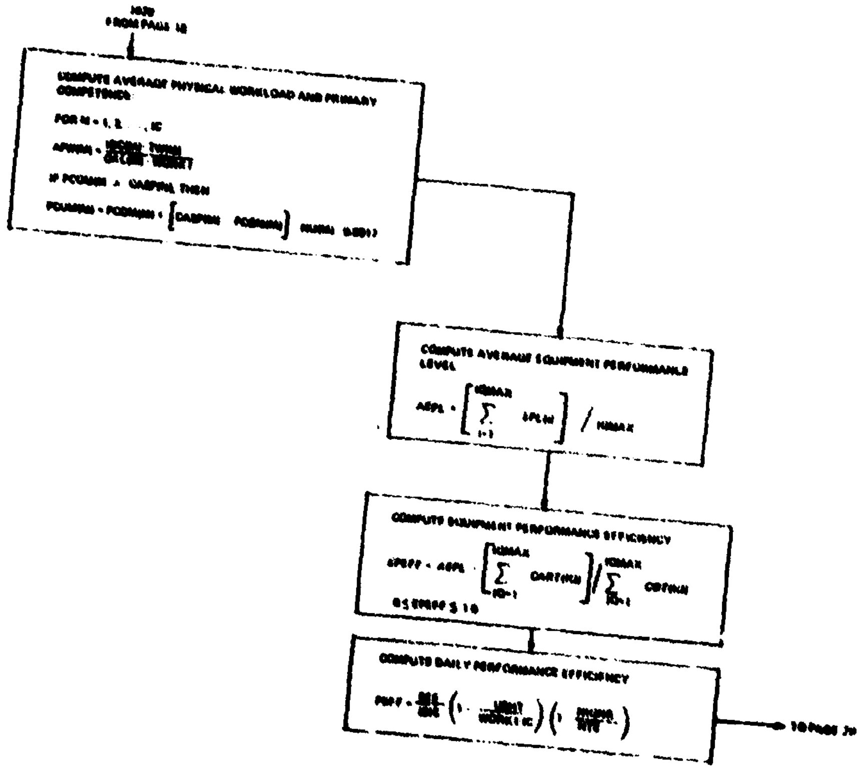
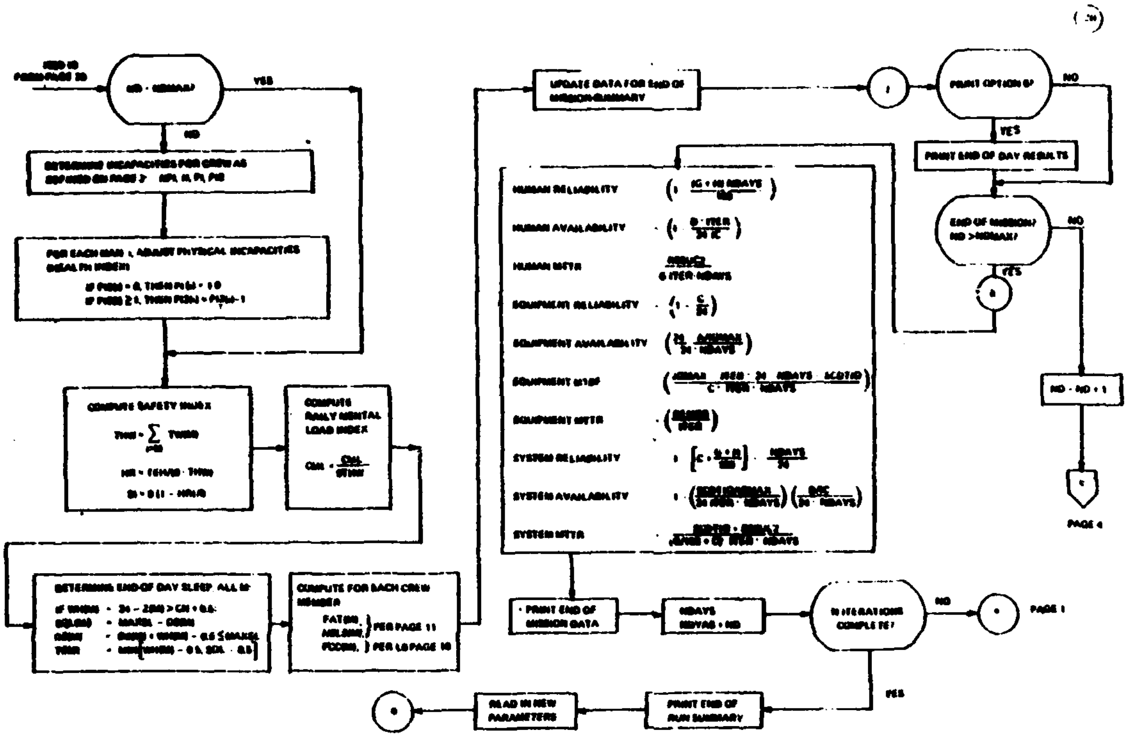
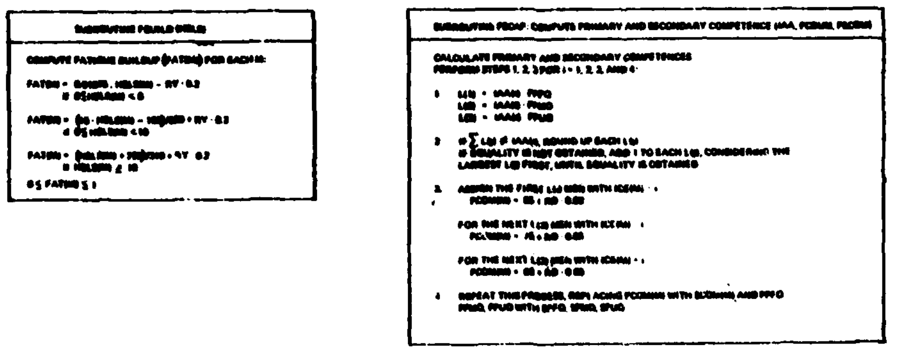



COMPUTE AVERAGE PHYSICAL WORKLOAD AND PRIMARY COMPETENCIES
COMPUTE AVERAGE EQUIPMENT PERFORMANCE LEVEL
COMPUTE EQUIPMENT PERFORMANCE EFFICIENCY
COMPUTE DAILY PERFORMANCE EFFICIENCY


YES
NO
PRINT OPTION 6?
PRINT END OF DAY RESULTS
END OF MISSION?
COMPUTE SAFETY INDEX
COMPUTE DAILY MENTAL LOAD INDEX
DETERMINE END OF DAY SLEEP, ALL M
COMPUTE FOR EACH CREW MEMBER
HUMAN RELIABILITY
HUMAN AVAILABILITY
HUMAN MTTR
EQUIPMENT RELIABILITY
EQUIPMENT AVAILABILITY
EQUIPMENT MTBF
EQUIPMENT MTTR
SYSTEM RELIABILITY
SYSTEM AVAILABILITY
SYSTEM MTTR
PRINT END OF MISSION DATA
ITERATIONS COMPLETE?
PAGE 1
PAGE 4
READ IN NEW PARAMETERS
PRINT END OF RUN SUMMARY

21



APPENDIX D INPUT DATA CARD FORMATS FOR 4-20 MAN DIGITAL SIMULATION MODEL

Simulation Input Data Preparation

Input for the intermediate size crew simulation model are initially prepared in NAMELIST and final field formats. Actual card layout and sequencing information for these formats are given in detail in this Appendix, and correspond to the types of data presented in Table B-1.

Table B-1

Types of Punched Card Format

Card Format	Type of Data
1	Number of iterations
2	Title
3	Tape input and number of days
4	Parameters
5	Personnel
6	Equipment repair events
7	Emergency events
8	Event type data
9	Sequence data

In the NAMELIST format, data are punched sequentially in card columns 2 through 72 without regard for column assisgnments. A comma separates each input number. Thus, all arrays must be completed with zeros. For example, the cross training probability matrix must have 10 x 10 entries even in the case that there are fewer than 10 types of personnel to be simulated.

If the simulation calls for more than one iteration, the input routine dumps all input data, except for the parameters and personnel data, onto a magnetic tape. This tape is then read in the subsequent iterations. A tape created in this fashion can be used to supply input for future simulations.

The sequencing, content and structure of the input data rules follow:

Title Cards

Description		FORTRAN	Format	Value
Card Format 1	Number of iterations	NKASES	I3	___ ___ ___
Card Format 2	Title	HEADR	12A6	72 spaces
Card Format 3	Tape input option (000= card, 001= tape)	ITAP	I3	___ ___ ___
	Number of days simulated	NDMAX	I3	___ ___ ___

Input Parameter - Card Format 4

Description	FORTRAN	Value
		$PARAM NFP2/FP2=
Average psychological stress threshold	APST	______,
Number of hours worked after which no new assignments are made	WORK1	______,
Number of hours worked after which further work is unauthorized	WORK2	______,
Number of hours since last sleep period by average crew member at start of mission	SLEEP	______,
Catnap length number of hours below which is rest, and above which is sleep	CN	______,
Maximum sleep permitted per day (hours)	MAXSL	______,
Fatigue threshold-below which sleep is not authorized	TFAT	______,
Average crew pace (average= 1, Fast <1; Slow >1)	ACP	______,
Number of calories required by average crew member per day	CALRY	______,
Average short term power output for average crew member (calories/hour)	PWRRT	______,
Derating constant for acceptable performance	K7	______,
Fraction to which man's physical capability reduced when daily quota of work is done	K1	______,
Effect of stress on performance on a two stress State	BE	______,
Average Aspiration Level	ASAP	______,
Per cent threshold for unmanned station hours	USHLIM	______,
Initial value of consumables on hand at start of mission for those expended on a units per hour basis 1______	KON(1)	______,
2______	KON(2)	______,
3______	KON(3)	______,
4______	KON(4)	______,
5______	KON(5)	______,
6______	KON(6)	______,
7______	KON(7)	______,
8______	KON(8)	______,
9______	KON(9)	______,
10______	KON(10)	______,

Title Cards Description	FORTRAN	VALUE
Consumable threshold for consumable 1, threshold 1	KONT(1,1)	________,
2	KONT(2,1)	________,
3	Kont(3,1)	________,
4	KONT(4,1)	________,
5	KONT(5,1)	________,
6	KONT(6,1)	________,
7	KONT(7,1)	________,
8	KONT(8,1)	________,
9	KONT(9,1)	________,
10	KONT(10,1)	________,
consumable 1, threshold 2	KONT(1,2)	________,
2	KONT(2,2)	________,
3	KONT(3,2)	________,
4	KONT(4,2)	________,
5	KONT(5,2)	________,
6	KONT(6,2)	________,
7	KONT(7,2)	________,
8	KONT(8,2)	________,
9	KONT(9,2)	________,
10	KONT(10,2)	________,
consumable 1, threshold 3	KONT(1,3)	________,
2	KONT(2,3)	________,
3	KONT(3,3)	________,
4	KONT(4,3)	________,
5	KONT(5,3)	________,
6	KONT(6,3)	________,
7	KONT(7,3)	________,
8	KONT(8,3)	________,
9	KONT(9,3)	________,
10	KONT(10,3)	________,
consumable 1, threshold 4	KONT(1,4)	________,
2	KONT(2,4)	________,
3	KONT(3,4)	________,
4	KONT(4,4)	________,
5	KONT(5,4)	________,
6	KONT(6,4)	________,
7	KONT(7,4)	________,
8	KONT(8,4)	________,
9	KONT(9,4)	________,
10	KONT(10,4)	________,
consumable 1, threshold 5	KONT(1,5)	________,
2	KONT(2,5)	________,
3	KONT(3,5)	________,
4	KONT(4,5)	________,
5	KONT(5,5)	________,
6	KONT(6,5)	________,
7	KONT(7,5)	________,
8	KONT(8,5)	________,
9	KONT(9,5)	________,
10	KONT(10,5)	________,

Title Cards

Description	FORTRAN	VALUE
Consumable threshold for consumable 1, threshold 6	KONT(1,6)	________,
2	KONT(2,6)	________,
3	KONT(3,6)	________,
4	KONT(4,6)	________,
5	KONT(5,6)	________,
6	KONT(6,6)	________,
7	KONT(7,6)	________,
8	KONT(8,6)	________,
9	KONT(9,6)	________,
10	KONT(10,6)	________,
consumable 1, threshold 7	KONT(1,7)	________,
2	KONT(2,7)	________,
3	KONT(3,7)	________,
4	KONT(4,7)	________,
5	KONT(5,7)	________,
6	KONT(6,7)	________,
7	KONT(7,7)	________,
8	KONT(8,7)	________,
9	KONT(9,7)	________,
10	KONT(10,7)	________,
consumable 1, threshold 8	KONT(1,8)	________,
2	KONT(2,8)	________,
3	KONT(3,8)	________,
4	KONT(4,8)	________,
5	KONT(5,8)	________,
6	KONT(6,8)	________,
7	KONT(7,8)	________,
8	KONT(8,8)	________,
9	KONT(9,8)	________,
10	KONT(10,8)	________,
consumable 1, threshold 9	KONT(1,9)	________,
2	KONT(2,9)	________,
3	KONT(3,9)	________,
4	KONT(4,9)	________,
5	KONT(5,9)	________,
6	KONT(6,9)	________,
7	KONT(7,9)	________,
8	KONT(8,9)	________,
9	KONT(9,9)	________,
10	KONT(10,9)	________,
consumable 1, threshold 10	KONT(1,10)	________,
2	KONT(2,10)	________,
3	KONT(3,10)	________,
4	KONT(4,10)	________,
5	KONT(5,10)	________,
6	KONT(6,10)	________,
7	KONT(7,10)	________,
8	KONT(8,10)	________,
9	KONT(9,10)	________,
10	KONT(10,10)	________,

Title Cards

Description		FORTRAN	VALUE
Initial value of consumable: (units)	1______________	KON1(1)	________,
	2______________	KON1(2)	________,
	3______________	KON1(3)	________,
	4______________	KON1(4)	________,
	5______________	KON1(5)	________,
	6______________	KON1(6)	________,
	7______________	KON1(7)	________,
	8______________	KON1(8)	________,
	9______________	KON1(9)	________,
	10______________	KON1(10)	________,
Consumable threshold for consumable	1, threshold 1	KONT1(1)	________,
	2	KONT1(2)	________,
	3	KONT1(3)	________,
	4	KONT1(4)	________,
	5	KONT1(5)	________,
	6	KONT1(6)	________,
	7	KONT1(7)	________,
	8	KONT1(8)	________,
	9	KONT1(9)	________,
	10	KONT1(10)	________,
consumable	1, threshold 2	KONT1(1,2)	________,
	2	KONT1(1,2)	________,
	3	KONT1(3,2)	________,
	4	KONT1(4,2)	________,
	5	KONT1(5,2)	________,
	6	KONT1(6,2)	________,
	7	KONT1(7,2)	________,
	8	KONT1(8,2)	________,
	9	KONT1(9,2)	________,
	10	KONT1(10,2)	________,
consumable	1, threshold 3	KONT1(1,3)	________,
	2	KONT1(2,3)	________,
	3	KONT1(3,3)	________,
	4	KONT1(4,3)	________,
	5	KONT1(5,3)	________,
	6	KONT1(6,3)	________,
	7	KONT1(7,3)	________,
	8	KONT1(8,3)	________,
	9	KONT1(9,3)	________,
	10	KONT1(10,3)	________,
consumable	1, threshold 4	KONT1(1,4)	________,
	2	KONT1(2,4)	________,
	3	KONT1(3,4)	________,
	4	KONT1(4,4)	________,
	5	KONT1(5,4)	________,
	6	KONT1(6,4)	________,
	7	KONT1(7,4)	________,
	8	KONT1(8,4)	________,
	9	KONT1(9,4)	________,
	10	KONT1(10,4)	________,

Title Cards Description		FORTRAN	VALUE
Consumable threshold for consumable	1, threshold 5	KONT1(1,5)	______,
	2	KONT1(2,5)	______,
	3	KONT1(3,5)	______,
	4	KONT1(4,5)	______,
	5	KONT1(5,5)	______,
	6	KONT1(6,5)	______,
	7	KONT1(7,5)	______,
	8	KONT1(8,5)	______,
	9	KONT1(9,5)	______,
	10	KONT1(10,5)	______,
consumable	1, threshold 6	KONT1(1,6)	______,
	2	KONT1(2,6)	______,
	3	KONT1(3,6)	______,
	4	KONT1(4,6)	______,
	5	KONT1(5,6)	______,
	6	KONT1(6,6)	______,
	7	KONT1(7,6)	______,
	8	KONT1(8,6)	______,
	9	KONT1(9,6)	______,
	10	KONT1(10,6)	______,
consumable	1, threshold 7	KONT1(1,7)	______,
	2	KONT1(2,7)	______,
	3	KONT1(3,7)	______,
	4	KONT1(4,7)	______,
	5	KONT1(5,7)	______,
	6	KONT1(6,7)	______,
	7	KONT1(7,7)	______,
	8	KONT1(8,7)	______,
	9	KONT1(9,7)	______,
	10	KONT1(10,7)	______,
consumable	1, threshold 8	KONT1(1,8)	______,
	2	KONT1(2,8)	______,
	3	KONT1(3,8)	______,
	4	KONT1(4,8)	______,
	5	KONT1(5,8)	______,
	6	KONT1(6,8)	______,
	7	KONT1(7,8)	______,
	8	KONT1(8,8)	______,
	9	KONT1(9,8)	______,
	10	KONT1(10,8)	______,
consumable	1, threshold 9	KONT1(1,9))	______,
	2	KONT1(2,9)	______,
	3	KONT1(3,9)	______,
	4	KONT1(4,9)	______,
	5	KONT1(5,9)	______,
	6	KONT1(6,9)	______,
	7	KONT1(7,9)	______,
	8	KONT1(8,9)	______,
	9	KONT1(9,9)	______,
	10	KONT1(10,9)	______,

Title Cards

Description		FORTRAN	VALUE
Consumable threshold for consumable	1, threshold 10	KONT1(1,10)	____,
	2	KONT1(2,10)	____,
	3	KONT1(3,10)	____,
	4	KONT1(4,10)	____,
	5	KONT1(5,10)	____,
	6	KONT1(6,10)	____,
	7	KONT1(7,10)	____,
	8	KONT1(8,10)	____,
	9	KONT1(9,10)	____,
	10	KONT1(10,10)	____,
Sea State			
Description and height of waves in feet)	0 -- calm, glassy	SESTA(1)	____,
	1 -- rippled, 0-1	SESTA(2)	____,
	2 -- smooth, 1-2	SESTA(3)	____,
	3 -- slight, 2-4	SESTA(4)	____,
	4 -- moderate, 4-8	SESTA(5)	____,
	5 -- rough, 8-13	SESTA(6)	____,
	6 -- very rough, 13-20	SESTA(7)	____,
	7 -- high, 20-30	SESTA(8)	____,
	8 -- very high, 30-45	SESTA(9)	____,
	9 -- exceptionally high, over 45	SESTA(10)	1.0,
Intermittent reliability--electronic equipment		RELI(1)	____,
Intermittent reliability--electrical equipment		RELI(2)	____,
Intermittent reliability--electromechanical equipment		RELI(3)	____,
Intermittent reliability--mechanical equipment		RELI(4)	____,
Number of mission iterations			NIP2/IP2=
Number of iterations per computer run		N	____,
Essentiality threshold, below which an event is ignored (1-100)		IET	____,
Indicators for output recording options		IND(1)	_,
Print all inputs (1), or parameters only (0)		IND(2)	_,
Print (1), or don't print (0): crew initial conditions		IND(3)	_,
: day numbers of 1st. repair, emergencies		IND(4)	_,
Print detailed event results for all events beginning with day		IND(5)	_,
Print end of day results for all days beginning with day		IND(6)	_,
Print (1), or don't print (0) mission results by individual man		IND(7)	_$

Personnel Data-Card Format 5

Title Cards Description	FORTRAN	VALUE $PERSNL NFP1/FP1
Mean body weight of total population (lbs.)	WT	______,
Standard deviation of population body weight (lbs.)	SIGWT	______,
Fraction of the crew fully qualified in prime-specialty	PPFQ	______,
Fraction of the crew minimally qualified in prime specialty	PPMQ	______,
Fraction of the crew unqualified in prime specialty	PPUQ	______,
Fraction of the crew qualified in second specialty	SPFQ	______,
Fraction of the crew minimally qualified in second specialty	SPUQ	______,
Avg. number of man days between physical incapacitations	MFI	______,
Avg. duration of incapacity (days)	PID	______,
Physical capability constant, a value yielded zero physical capability due to over exertion	ZPC	______,

Crosstraining probability - enter fractional values representing the probability of man with a given specialty also being trained in each other specialty. Diagonal elements are usually zero if a man is not to have the same primary and secondary specialty.

prime specialty

second specialty	FORTRAN	1	2	3	4	5	6	7	8	9	10
______	PTT(1-10,1)	__,	__,	__,	__,	__,	__,	__,	__,	__,	__,
______	PTT(1-10,2)	__,	__,	__,	__,	__,	__,	__,	__,	__,	__,
______	PTT(1-10,3)	__,	__,	__,	__,	__,	__,	__,	__,	__,	__,
______	PTT(1-10,4)	__,	__,	__,	__,	__,	__,	__,	__,	__,	__,
______	PTT(1-10,5)	__,	__,	__,	__,	__,	__,	__,	__,	__,	__,
______	PTT(1-10,6)	__,	__,	__,	__,	__,	__,	__,	__,	__,	__,
______	PTT(1-10,7)	__,	__,	__,	__,	__,	__,	__,	__,	__,	__,
______	PTT(1-10,8)	__,	__,	__,	__,	__,	__,	__,	__,	__,	__,
______	PTT(1-10,9)	__,	__,	__,	__,	__,	__,	__,	__,	__,	__,
______	PTT(1-10,10)	__,	__,	__,	__,	__,	__,	__,	__,	__,	__,

Crew composition
number of men in each specialty at each crew eschelon (rank or level)

prime specialty

NIP1/IP1=

eschelon or level		1	2	3	4	5	6	7	8	9	10
______	MEN(1-10,1)	__,	__,	__,	__,	__,	__,	__,	__,	__,	__,
______	MEN(1-10,2)	__,	__,	__,	__,	__,	__,	__,	__,	__,	__,
______	MEN(1-10,3)	__,	__,	__,	__,	__,	__,	__,	__,	__,	__,
______	MEN(1-10,4)	__,	__,	__,	__,	__,	__,	__,	__,	__,	__,

Title Cards

Description		FORTRAN	VALUE
Number of duty shifts per 24 hour day		NDS	________,
Crew duty shift assignment			
Man	1	IDS(1-6,1)	_,_,_,_,_,_,
	2	IDS(1-6,2)	_,_,_,_,_,_,
	3	IDS(1-6,3)	_,_,_,_,_,_,
	4	IDS(1-6,4)	_,_,_,_,_,_,
	5	IDS(1-6,5)	_,_,_,_,_,_,
	6	IDS(1-6,6)	_,_,_,_,_,_,
	7	IDS(1-6,7)	_,_,_,_,_,_,
	8	IDS(1-6,8)	_,_,_,_,_,_,
	9	IDS(1-6,9)	_,_,_,_,_,_,
	10	IDS(1-6,10)	_,_,_,_,_,_,
	11	IDS(1-6,11)	_,_,_,_,_,_,
	12	IDS(1-6,12)	_,_,_,_,_,_,
	13	IDS(1-6,13)	_,_,_,_,_,_,
	14	IDS(1-6,14)	_,_,_,_,_,_,
	15	IDS(1-6,15)	_,_,_,_,_,_,
	16	IDS(1-6,16)	_,_,_,_,_,_,
	17	IDS(1-6,17)	_,_,_,_,_,_,
	18	IDS(1-6,18)	_,_,_,_,_,_,
	19	IDS(1-6,19)	_,_,_,_,_,_,
	20	IDS(1-6,20)	_,_,_,_,_,_$

For each man enter $\frac{24}{NDS}$ IDS of one or zero, i.e., one value for each shift:

0 (man not assigned to this shift)
1 (man is assigned to this shift)

Fill in matrix with zeros if necessary.

EQUIPMENT REPAIR DATA - CARD FORMAT 6

Complete the following data for each equipment repair family.

Equipment Name______________________________ Equipment Number____________________

Title Cards

Description	FORTRAN	VALUE
Equipment repair		* *$EQREVT*
		* *NFP4/FP4=*
Reliability (days between hard failure)	RELH	______,
Intermittent failure duration (hours)	TUI	______,
For each event in the repair family		
Event 1		
Repair maximum duration (minutes)	DTR	______,
Probability of next event	PRB(1-3,1)	___,___,___,
Data change number	IEDC(1-3,1)	___,___,___,
Data change value	EDCV(1-3,1)	___,___,___,
Event 2		
Repair maximum duration (minutes)	DTR	______,
Probability of next event	PRB(1-3,2)	___,___,___,
Data change number	IEDC(1-3,2)	___,___,___,
Data change value	EDCV(1-3,2)	___,___,___,
Event 3		
Repair maximum duration (minutes)	DTR	______,
Probability of next event	PRB(1-3,3)	___,___,___,
Data change number	IEDC(1-3,3)	___,___,___,
Data change value	EDCV(1-3,3)	___,___,___,
Event 4		
Repair maximum duration (minutes)	DTR	______,
Probability of next event	PRB(1-3,4)	___,___,___,
Data change number	IEDC(1-3,4)	___,___,___,
Data change value	EDCV(1-3,4)	___,___,___,
Event 5		
Repair maximum duration (minutes)	DTR	______,
Probability of next event	PRB(1-3,5)	___,___,___,
Data change number	IEDC(1-3,5)	___,___,___,
Data change value	EDCV(1-3,5)	___,___,___,
Event 6		
Repair maximum duration (minutes)	DTR	______,
Probability of next event	PRB(1-3,6)	___,___,___,
Data change number	IEDC(1-3,6)	___,___,___,
Data change value	EDCV(1-3,6)	___,___,___,
Event 7		
Repair maximum duration (minutes)	DTR	______,
Probability of next event	PRB(1-3,7)	___,___,___,
Data change number	IEDC(1-3,7)	___,___,___,
Data change value	EDCV(1-3,7)	___,___,___,

*Punch these cards for first equipment repair family only.

Title Cards

Description	FORTRAN	Value
Event 8		
Repair maximum duration (minutes)	DTR	____,
Probability of next event	PRB(1-3,8)	____,____,____,
Data change number	IEDC(1-3,8)	____,____,____,
Data change value	EDCV(1-3,8)	____,____,____,
Event 9		
Repair maximum duration (minutes)	DTR	____,
Probability of next event	PRB(1-3,9)	____,____,____,
Data change number	IEDC(1-3,9)	____,____,____,
Data change value	EDCV(1-3,9)	____,____,____,
Event 10		
Repair maximum duration (minutes)	DTR	____,
Probability of next event	PRB(1-3,10)	____,____,____,
Data change number	IEDC(1-3,10)	____,____,____,
Data change value	EDCV(1-3,10)	____,____,____,
Event 11		
Repair maximum duration (minutes)	DTR	____,
Probability of next event	PRB(1-3,11)	____,____,____,
Data change number	IEDC(1-3,11)	____,____,____,
Data change value	EDCV(1-3,11)	____,____,____,
Event 12		
Repair maximum duration (minutes)	DTR	____,
Probability of next event	PRB(1-3,12)	____,____,____,
Data change number	IEDC(1-3,12)	____,____,____,
Data change value	EDCV(1-3,12)	____,____,____,

Equipment Repair Data

Complete the following data sheet for each equipment repair family, i.e., each equipment type.

Title Cards

Description	FORTRAN	VALUE
Total number of equipments	NEQRE	NIP4/IP4=
Complete the following data sheet for each equipment repair in family, i.e. each equipment type		
Repair description		
Description (72 digits)		67______,
Consumable threshold see number (units/hour)	TSR	______,
Comsumable threshold (units)	TSR1	______,
Number of repair events in family	IRE	______,
Family number	IEFN	______,
Event family members		
Event 1 Type number	IETYP	______,
Precedent events	IPE	______,
Next events	NX(1-3,1)	___,___,___,
Repair/Touch up (1,2,3)	RTU	______,
Event family indicator (0,1,2)	IFOI	______,
Event 2 Type number	IETYP	______,
Precedent events	IPE	______,
Next events	NX(1-3,2)	___,___,___,
Repair/Touch up	RTU	______,
Event family indicator	IFOI	______,
Event 3 Type number	IETYP	______,
Precedent events	IPE	______,
Next events	NX(1-3,3)	___,___,___,
Repair/Touch up	RTU	______,
Event family indicator	IFOI	______,
Event 4 Type number	IETYP	______,
Precedent events	IPE	______,
Next events	NX(1-3,4)	___,___,___,
Repair/Touch up	RTU	______,
Event family indicator	IFOI	______,
Event 5 Type number	IETYP	______,
Precedent events	IPE	______,
Next events	NX(1-3,5)	___,___,___,
Repair/Touch up	RTU	______,
Event family indicator	IFOI	______,
Event 6 Type number	IETYP	______,
Precedent events	IPE	______,
Next events	NX(1-3,6)	___,___,___,
Repair/Touch up	RTU	______,
Event family indicator	IFOI	______,
Event 7 Type number	IETYP	______,
Precedent events	IPE	______,
Next events	NX(1-3,7)	___,___,___,
Repair/Touch up	RTU	______,
Event family indicator	IFOI	______,

Title Cards

Description	FORTRAN	VALUE
Event 8 Type number	IETYP	______,
Precedent events	IPE	______,
Next events	NX(1-3,8)	__,__,__,
Repair/Touch up	RTU	______,
Event family indicator	IFOI	______,
Event 9 Type number	IETYP	______,
Precedent events	IPE	
next events	NX(1-3,9)	__,__,__,
Repair/Touch up	RTU	______,
Event family indicator	IFOI	______,
Event 10 Type number	IETYP	______
Precedent events	IPE	______,
Next events	NX(1-3,10)	__,__,__,
Repair/Touch up	RTU	______,
Event family indicator	IFOI	______,
Event 11 Type number	IETYP	______,
Precedent events	IPE	______,
Next events	NX(1-3,11)	__,__,__,
Repair/Touch up	RTU	______,
Event family indicator	IFOI	______,
Event 12 Type number	IETYP	______,
Precedent events	IPE	______,
Next events	NX(1-3,12)	__,__,__,
Repair/Touch up	RTU	______,
Event family indicator	IFOI	______ $

*Punch only after end of all equipment repair data.

EMERGENCY EVENT DATA - CARD FORMAT 7

Repeat following data for each emergency type.

Emergency Number________________________

Title Cards

Description	FORTRAN	Value
		$EMREVT
		NIP5/IP5=
Emergencies		
Emergency: Description		67H______,
Essentiality	IESSE	______,
Number of men required (by type)	NREQE(1-5,1)	_,_,_,_,_,
	NREQE(6-10,1)	_,_,_,_,_,
Mental load	LODME	______,
Rate of consumable expenditure for those expended on a units/hour basis	IRCE(1-5,1)	_,_,_,_,_,
	IRCE(6-10,1)	_,_,_,_,_,
Threshold set for units/hours/consumables	TSE	______,
Rate of consumable expenditures (units)	IRCE1(1-5,1)	_,_,_,_,_,
	IRCE1(6-10,1)	_,_,_,_,_,
Threshold set for units/consumables	TSE1	______,
Hazard class	IHE	______,
Energy consumption by personnel types (calories/hr)	IECE(1-5,1)	_,_,_,_,_,
	IECE(6-10,1)	_,_,_,_,_,
Mean number of days between occurrance of this type of emergency	NDBE	______,
Repeat following data for each emergency		
		NFP5/FP5=
Average recovery time (hours)	ART	______,
Average standard deviation of recovery time (hours)	ASDE	______,
Duration target for recovery from this emergency type (hours)	DTE	______, $

EVENT TYPE DATA - CARD FORMAT 8

Event type number________________________

Title Cards

Description	FORTRAN	Value
Event type data		*$TYPE NIP5/IP5=*
Description of event type		67H______,
Essentiality (0 to 100)	IESS	______,
Number of men required (by type)	NREQ(1-5,1)	_,_,_,_,_,
	NREQ(6-10,1)	_,_,_,_,_,
Mental load	LODM	______,
Kind of event end time (1= fixed end; 2= variable end)	KE	______,
Kind of event (1= normal; 2= training)	INT	______,
Rate of expenditure of consumables (units/hours)	IRC(1-5,1)	_,_,_,_,_,
	IRC(6-10,1)	_,_,_,_,_,
Rate of expenditure of consumables (units)	IRC1(1-5,1)	_,_,_,_,_,
	IRC1(6-10,1)	_,_,_,_,_,
Hazard class (1-3 low, 4-6 medium, 7-9 heavy)	IH	______,
Energy consumption (cal./hr.)	IEC(1-5,1)	_,_,_,_,_,
	IEC(6-10,1)	_,_,_,_,_,
Number of equipments required*	NIQR	______,
Equipments required*	IQR(1-6)	_,_,_,_,_, ____,
Class	ICLASS	______,
Complete entry of all Event type data, IESS to ICLASS, for all Event types before entering duration data.	ADUR	______,
	ASD	______, $

Precede duration data by NFPS/FP5 =

Note: Each NAMELIST entry (ex $TYPE NIP5/IP5 =) occurs only once. It is not repeated before each task type.

Average duration (hours)

Average standard deviation

*For event type data which are for equipment repair, NIQR must be 1 (one equipment being repaired) and IQR(1-6) should be of the form (X,0,0,0,0,0) where X is the number of the equipment to be repaired. For scheduled event types where, say equipment numbers 1,3, and 11 are to be used in the event, NIQR= 3 and IQR(1-6)= (1,3,11,0,0,0).

SCHEDULED EVENT SEQUENCE DATA - CARD FORMAT 9

Scheduled events title card	FORTRAN	Format	Value
(Input card not free format)			
Day number for this iteration	ND	I3	___
Number of scheduled events this iteration	NOSE	I3	___
Title for this day		11A6	(66 spaces)

Complete the following data for each scheduled event:

Scheduled Event Name________________________ Scheduled Event Number____________

Scheduled Events	FORTRAN	Value
		$SCHEVT
		NIP3/IP3=
Event type	IETYP	______,
Precedent event sequence number which must be completed before current event	IPE	______,
Threshold set (units/hour)	TS	______,
Threshold set (units)	TS1	______,
Repeat/Touchup code (1= repeat; 2= touchup, 3= no action)	RTU	______,
Event family indicator	IFOI	______,
Number in family	NIF	______,
Family number	IEFN	______,
Next events	NX(1-3,1)	__,__,__,
(Repeat for each scheduled event)		
		NFP3/FP3=
Time limit	TL	______,
Start time (hours)	ST	______,
Probability of alternatives	PRB(1-3,1)	______,
Data change number	IEDC(1-3,1)	______,
Data change value	EDCV(1-3,1)	______, $

(Repeat for each scheduled event)

APPENDIX E CONFIDENCE BOUND ESTIMATION

APPENDIX E

CONFIDENCE BOUND ESTIMATION

E.1 Introduction

In this section, two methods for estimating the confidence bounds of a lognormal distribution are described. The first method estimates the confidence bound due to the expected sample variations of the parameter estimates. The second method estimates the confidence bound due to the noise effect, which is the random variations from the smooth envelope of a true lognormal distribution. Normally, when the random sample deviations from the true lognormal distribution are negligible, only the first method will be required. Otherwise, the confidence bounds of methods 1 and 2 should be combined to provide a conservative result.

In order to clearly illustrate the estimation procedures, the the sample elapsed (or repair) times (x) of table E-1 are used.

Initially, the lognormal regression line is estimated, by a shortcut method, as a straight line connecting the estimated median and the 95th percentile point.

The estimated median of repair time = $MTTR_G$ = x(50%) = 1.234*.

The expected x (95%) = $MTTR_G \exp(1.645\sigma/0.434)$. $\hat{\sigma}$ (the estimate of σ) is computed from equation (E-2) and is equal to 0.623/2.3, or roughly 0.271. Therefore, the expected x (95%) = 1.234 exp [1.645 (0.271)/0.434] = 3.443.

The regression line can then be plotted on lognormal paper in figure E-1 by joining the two points x(50%) and x(95%). The detailed procedures for estimating the other data points in figure E-1 are explained in the following sections.

E.2 Procedure for Estimating Confidence Bound Due To Variations of Parameter Estimates (Method 1)

E.2.1 Calculation Procedure. This method assumes the random variation between x and a true lognormal distribution is negligible so that equation (E-1) holds.

*From Table E-1, $MTTR_G = e^{\hat{\mu}} = 1.234$.

<u>Legend</u> | <u>Data Source</u>

Legend	Data Source
▲ - ▲ Estimated Lognormal Regression Line	Paragraph X-1
X X X Discrete Sample Data Points	Table X-1, 2, Colums (3) & (5)
● - ● 95% Confidence Bound, Method 2	Table X-2, Columns (3) & (12) or (13)
▫ - ▫ 96% Confidence Bound, Method 1	Table X-1, Columns (3) & (8) or (9)
c - c≥95% Confidence Bound, Combined Methods 1 & 2	Table X-3, Columns (3) & (8) or (9)

Note: X Sample data points are either above or below the regression line depending on whether ε is positive or negative - see Table X-2, Column (7).

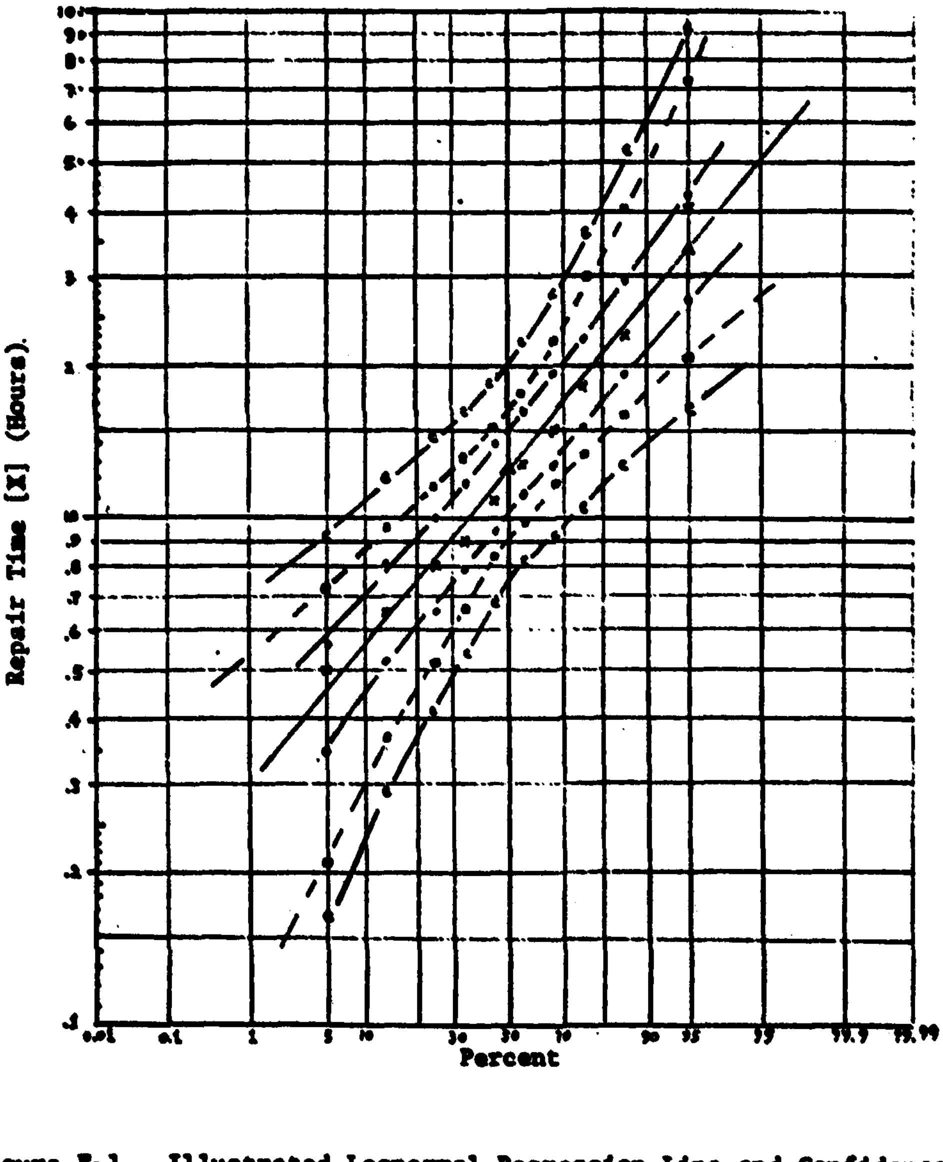


Figure E-1. Illustrated Lognormal Regression Line and Confidence Bounds

$$\ln X = Y' = \mu' + \sigma' Z \qquad \text{(E-1)}$$

X - random variable of the entire population; X is lognormally distributed

x - sampled random variable from the population

Y' - normally distributed with a mean μ' and variance σ'^2

μ' - true mean of $Y' = \sum^{N} \ln X/N = \sum^{N} Y'/N$

$\hat{\mu}'$ - estimate of $\mu' = \sum^{n} \ln X/n$

σ' - true standard deviation of $\ln X = \sqrt{\dfrac{\sum^{N}(\ln X-\mu')^2}{N}}$

$\hat{\sigma}'$ - estimate of σ' [see equations (E-2) and (E-3)]

y' - natural logarithm of x or lnx

N - population size (in many cases N is extremely large)

n - sample size, in this section n is assumed to equal M.

σ - true standard deviation of log X

$\hat{\sigma}$ - estimate of σ

Z - standardized normal variate

α - significance level

M - interval size

$$\hat{\sigma}' = \sqrt{\frac{\Sigma(\ln x)^2 - (\Sigma^{n} \ln x)^2/n}{n-1}}$$

$$= 2.3\hat{\sigma} = 2.3\sqrt{\frac{\sum^{n}(\log x)^2 - (\sum^{n}\log x)^2/n}{n-1}} \qquad \text{(E-2)*}$$

*Equation (E-2) should be used when sample size is small; equation (E-3) is easier to estimate σ', but sample size should be equal or greater than 20.

For n (sample size) $\geq$ 20, ln(10) = 2.3

$$\hat{\sigma} = 2.3\hat{\sigma} = 2.3 \sqrt{\frac{M}{M-1}} \sqrt{\frac{1}{1.15} \log \left(\sum^{n} x/n\right)/D} \qquad \text{(E-3)*}$$

when $D = \text{Antilog} \left(\sum^{n} \log x/n\right)$

Since $\hat{\mu}'$ is a random variable which (according to the central limit theorem) is normally distributed with the mean μ' and the standard deviation $\sigma'/\sqrt{n}$, the confidence interval of μ' can be estimated by:

$$\text{Probability } (\hat{\mu}'_L < \mu' < \mu'_H)$$

$$= \text{probability} \left\{ \left(\hat{\mu}' - t_{\underset{\text{d.f.}}{\alpha/2(n-1)}} \frac{\hat{\sigma}'}{\sqrt{n}}\right) < \mu' < \left(\hat{\mu}' + t_{\underset{\text{d.f.}}{\alpha/2(n-1)}} \frac{\hat{\sigma}}{\sqrt{n}}\right) \right\} = 1 - \alpha \qquad \text{(E-4)}$$

Since lnx is normally distributed, and $(n-1)\ \hat{\sigma}'^2$ is equal to $\sum^{n} (\ln x - \hat{\mu}')^2$, the confidence bound of σ'^2 can be estimated by equation (E-5). Note that one degree of freedom is lost due to the estimate of μ'.

$$\text{Probability } (\hat{\sigma}'^2_L < \hat{\sigma}'^2 < \hat{\sigma}'^2_H)$$

$$= \text{probability} \left\{ \frac{(n-1)\hat{\sigma}'^2}{\chi^2\ (1 - \alpha/2)\ (n-1,\ \text{d.f.})} < \sigma'^2 < \frac{(n-1)\ \hat{\sigma}'^2}{\chi^2_{\alpha/2}\ (n-1\ \text{d.f.})} \right\} \qquad \text{(E-5)}$$

$$= 1 - \alpha$$

*In equation (E-3), the correction factor $\sqrt{M/(M-1)}$ is derived empirically. For instance, using the example illustrated in page 80 of "Maintainability Principles and Practices," Blanchard and Lowery, the standard deviation estimate based on 27 samples without correction factor resulted in 1.724 percent error. When correction factor is used, the error is reduced to 0.155 percent.

According to the proof provided in section 10.4 of "Introduction to the Theory of Statistics," (Mood, A. and Graybill, F., McGraw-Hill, 1963), the estimates of the mean and variance of x are statistically independent; consequently, their convariance is zero. This permits us to set up a deterministic confidence bound of x values for a fixed standard normal variate Z by estimating the worst combinations of $\hat{\mu}'_L$, $\hat{\mu}'_H$, $\hat{\sigma}'_L$ and $\hat{\sigma}'_H$.

$$\left.\begin{aligned} \hat{X}\text{ (upper)} &= \exp\left[Z(\hat{\sigma}'_H) + \hat{\mu}'_H\right] \\ \hat{X}\text{ (lower)} &= \exp\left[Z(\hat{\sigma}'_L) + \hat{\mu}'_L\right] \end{aligned}\right\} \begin{aligned} &\text{for all } Z \geq 0 \\ &\text{(Z positive)} \end{aligned} \qquad \text{(E-6)}$$

$$\left.\begin{aligned} \hat{X}\text{ (upper)} &= \exp\left[Z(\hat{\sigma}'_L) + \hat{\mu}'_H\right] \\ \hat{X}\text{ (lower)} &= \exp\left[Z(\hat{\sigma}'_H) + \hat{\mu}'_L\right] \end{aligned}\right\} \begin{aligned} &\text{for all } Z \leq 0 \\ &\text{(Z negative)} \end{aligned} \qquad \text{(E-7)}$$

Since the probability of a parameter equal to (or exceeding) its estimated limits is α (or $< \alpha$), the joint probability of both parameters (μ' and σ') equaling (or exceeding) their respective limits is α^2 (or $<\alpha^2$); consequently, equation (E-8) can be established.

$$\text{Probability}\left[\hat{X}\text{(lower)} < X < \hat{X}\text{(upper)}\right] \geq 1 - \alpha^2 \qquad \text{(E-8)}$$

E.2.2 Example. Using the data from table E-1, rearrange the sample elapsed time (x) in the ascending order as recorded in table E-1, column (5). The remaining columns of table E-1 are described as follows: Columns (1) and (2) are self-explanatory, and column (3) records the midpoint of accumulative frequency of column (2). For instance, midpoint of 0 and 0.1 is 0.05, midpoint of 0.1 and 0.2 is 0.15, etc. A simple formula for estimating midpoint accumulative frequency (F') is shown in equation (E-9).

$$\frac{2i-1}{2M} = F' \qquad \text{(E-9)}$$

i = the sample sequence, which ranges from 1 to n

M = the total interval size, which is 10 in this example

F' = the midpoint accumulative frequency

Column (4) records the standardized normal variate value Z, which can be derived from a cumulative normal table with F' values as the inputs. Column (5) records sample data (x) in ascending order. Columns (6) through (9) data can be computed using equations (E-6) and (E-7).

TABLE E-1. CONFIDENCE BOUND DUE TO RANDOM SAMPLE VARIATIONS OF PARAMETER ESTIMATES, METHOD 1 DATA

(1) k	(2) Accum. Freq. (F)	(3) Midpoint F'	(4) Z	(5) Repair Time x	(6) lnx (upper)	(7) lnx (lower)	(8) $\hat{x}$ (upper)	(9) $\hat{x}$ (lower)
1	0.1	0.05	-1.645	0.5	-0.319	-1.565	0.727	0.209
2	0.2	0.15	-1.04	0.65	-0.024	-1.013	0.976	0.363
3	0.3	0.25	-0.675	0.8	0.154	-0.679	1.166	0.507
4	0.4	0.35	-0.386	0.9	0.295	-0.416	1.343	0.660
5	0.5	0.45	-0.125	1.1	0.422	-0.177	1.525	0.838
6	0.6	0.55	0.125	1.25	0.597	-0.001	1.817	0.999
7	0.7	0.65	0.386	1.5	0.836	+0.126	2.306	1.134
8	0.8	0.75	0.675	1.8	1.100	0.267	3.004	1.306
9	0.9	0.85	1.04	2.3	1.43	0.445	4.195	1.560
10	1.0	0.95	1.645 $\Sigma Z=0$	4.1	1.987	0.740	7.294	2.095

In order to use equations (E-6) and (E-7), μ'_H, μ'_L, σ'_H, and σ'_L must first be computed. The computation procedures are illustrated as follows:

$$n = 10 = M$$

$$MTTR_G = \text{Antilog}\left(\sum^{n} \log x/n\right) = 1.234$$

$$\hat{\mu} = \ln\,(MTTR_G) = 0.210$$

$\hat{\sigma}$ estimated from equation (E-2) = 0.623

Let α = 20 percent. From a student's t table,

$$t_{0.2/2}(10 - 1,\ \text{d.f.}) = 1.383.$$

From equation (E-4):

$$\hat{\mu}'_L = \hat{\mu}' - t_{\alpha/2(n-1)\,\text{d.f.}} \frac{\hat{\sigma}}{\sqrt{n}} = -0.062$$

$$\hat{\mu}'_H = \hat{\mu}' + t_{\alpha/2(n-1)} \frac{\hat{\sigma}}{\sqrt{n}} = 0.483$$

From equation (E-5):

$$\hat{\sigma}'_H = \hat{\sigma}'\sqrt{\frac{(n-1)}{\chi^2(\alpha/2)(n-1)\ d.f.)}}$$

$$= 0.623 \times \sqrt{\frac{10-1}{4.17}} = 0.915$$

$$\hat{\sigma}'_L = \hat{\sigma}\sqrt{\frac{(n-1)}{\chi^2(1-0.2/2)\ (n-1,\ d.f.)}}$$

$$= 0.623 \times \sqrt{\frac{10-1}{14.7}} = 0.487$$

To compute data in columns (6) and (8) for $Z = +1.645$, equation (E-6) can be used as follows:

$$\ln\hat{X}\ (\text{upper}) = Z\ (\hat{\sigma}'_H) + \hat{\mu}'_H = 1.645 \times (0.915) + 0.483 = 1.987$$

$$\hat{X}\ (\text{upper}) = \exp\ [1.987] = 7.294$$

To compute columns (7) and (9) data for $Z = +1.645$, equation (E-6) can be used as follows:

$$\ln\hat{X}\ (\text{lower}) = Z(\hat{\sigma}'_L) + \hat{\mu}'_L = 1.645 \times (0.487) - 0.062 = 0.739$$

$$\hat{X}\ (\text{lower}) = \exp\ [0.739] = 2.095$$

Similarly, the other data of columns (6) through (9) can be computed; however, notice that equation (E-6) should be used for all positive Z values, and equation (E-7) should be used for all negative Z values.

The $\hat{X}$ (upper) and $\hat{X}$ (lower) values with their corresponding F' values are plotted in figure E-1 to provide Method 1 confidence bounds.

E.3 Procedures for Estimating Confidence Bound Due to Random Deviation from a True Lognormal Distribution, Method 2

Method 2 is based on a classical linear regression confidence bound computation procedure. The basic notations stated in section E-2 are unchanged; however, because the method is intended to estimate the confidence bound due to the random deviations from the smooth envelope of a true lognormal distribution, equation (E-1) in section E.2 should be replaced by equation (E-10) below:

$$\ln X = Y' = \mu' + \sigma' Z + \varepsilon \qquad \text{(E-10)}$$

ε is a nuisance variable that is assumed to be normally distributed about the regression line with a variance equal to σ^2_ε and a mean roughly equal to zero. If the true values of μ', σ', and σ_ε are known, the 95th percentile prediction interval for Y_o' would be simply:*

$$\mu' + \sigma' Z_o - 1.96\sigma_\varepsilon \text{ to } \mu' + \sigma' Z_o + 1.96\sigma_\varepsilon$$

Because all three parameters are unknown, we shall attempt to establish an interval in terms of their estimates. The variate $\hat{\varepsilon}\Delta = Y'_o - \hat{\mu}' - \hat{\sigma}' Z_o$ (or $\hat{\hat{\varepsilon}} = y'_o - \hat{\mu}' - \hat{\sigma}' Z_o$)** must also be normally distributed because it is a linear function of the normal variates Y'_o (or y'_o), $\hat{\mu}'$, and $\hat{\sigma}'$. The mean of $\hat{\hat{\varepsilon}}$ is zero and its variance $\sigma_{\hat{\varepsilon}}^2$, is:

$$\begin{aligned}\sigma_{\hat{\varepsilon}}^2 &= E\,(\hat{\varepsilon}^2)\\ &= E\,(y'_o - \hat{\mu}' - \hat{\sigma}' Z_o)^2\\ &= \sigma_\varepsilon^2\left[1 + \frac{1}{n} + \frac{Zo^2}{\sum^n Z^2}\right]\end{aligned} \qquad \text{(E-11)}\dagger$$

The meaning of the terms on the right hand side of equation (E-11) are explained as follows: the first term is the expected variance of y'_o or simply σ_ε^2, the second term is the variance contribution to $\sigma_{\hat{\varepsilon}}^2$ due to the random variable $\hat{\mu}$, and the third term is the variance contribution to $\sigma_{\hat{\varepsilon}}^2$ due to the random variable $\hat{\sigma}'$.

Since the variate $\hat{\varepsilon}/\sigma_{\hat{\varepsilon}}$ is normally distributed with zero mean and unit variance and is distributed independent of $\hat{\sigma}_\varepsilon^2\,(n-2)/\sigma^2$ which has a chi-square distribution, equations (E-12) and (E-13) can be established:††

$$t = \frac{\hat{\varepsilon}/\sigma_{\hat{\varepsilon}}}{\sqrt{\hat{\sigma}_\varepsilon^2/\sigma_\varepsilon^2}} \qquad \text{(E-12)}$$

---

*Y'_o indicates a specific Y' value, that corresponds with Z_o, which is a specific value of Z; y' is a subset of Y'.

**$\hat{\varepsilon}$ is the estimate of ε; $\hat{\hat{\varepsilon}}$ is an estimate of $\hat{\varepsilon}$.

†Equation (E-11) is true only when $\sum^n Z/n$ or $\bar{Z}$ is zero. For the lognormal distribution application, this condition is quite appropriate because at the median (50th percentile) of a distribution, Z is always zero. See derivation in: (1) Mood, A., and Graybill, F., "Introduction to the Theory of Statistics," McGraw-Hill, 1963, Section 10.4; and (2) NBS HDBK 91, "Experimental Statistics," August 1963, Chapter 5.

††$\hat{\sigma}_\varepsilon^2 = \sum^n (y' - \hat{\mu} - \hat{\sigma}' Z)^2/(n-2)$; two degrees of feedom are lost due to the estimates of μ' and σ'.

$$\text{Probability}\left\{(\hat{\mu}' + \hat{\sigma}' Z_o - A) < y'_o < (\hat{\mu}' + \hat{\sigma}' Z_o + A)\right\} = 1 - \alpha$$

where: (E-13)

$$A = t_{\alpha/2}(n\text{-}2 \text{ d.f.})\ \hat{\sigma}_\varepsilon \sqrt{1 + \frac{1}{n} + Z_o^2 / \sum^n Z^2}$$

E.3.1 Comments on Equation (E-13). Note that y'_o is a subset of Y'_o, or simply its estimate. The y'_o range predicted by equation (E-13) is only a subset of Y'_o range—not the expected maximum range of Y'_o with $(1 - \alpha)$ probability. The sample result shown in figure E-1 points out that equation (E-13) only effectively predicts the confidence interval for the random sample deviations from the smooth envelope of the lognormal distribution. To predict the expected maximum Y'_o range, equation (E-14) in section E.4 should be consulted. In other words, equation (E-13) holds only for a single prediction based on μ, σ, and σ_ε; the relation has meaning only if μ', σ', and σ_ε are re-estimated each time a prediction on y'_o is made.

E.3.2 Illustrative Example (Method 2). Again, the repair time data from table E-1 are used for the illustrated example. As explained in section E.2, $\hat{\mu}'$ is 0.210, $\hat{\sigma}$ is 0.623, and n is 10. α is chosen to be 0.10 and $t_{\alpha/2}(n\text{-}2, \text{d.f.})$ is 2.306. Table E-2 data computation procedures are explained as follows.

Columns (1) through (5) data of tables E-1 and E-2 are identified; the descriptions of these data are the same as that stated in section E.2.

Columns (6) through (8) are self-explanatory. Note that sum of column (7) data should be close to zero to ensure that the regression line achieved by the shortcut method shown in section E.1 is roughly equivalent to that by the classical linear regression line estimation approach. Also, note that the unbiased estimate of σ_ε is:

$$\hat{\sigma}_\varepsilon = \sqrt{\frac{\text{Sum of Column (8) table E-2}}{n-2}} \qquad \text{(E-14)}$$

$$= \sqrt{\frac{0.062}{10-2}} = 0.088$$

Column (9) "A" data can be computed by inserting the appropriate parameter values into equation (E-13). Note that in this illustrated example $\sum^{10} Z^2$ is roughly 8.800.

Columns (10) through (13) data derivation procedures are self-explanatory. Columns (10) and (11) provide y'_o ranges defined by equation (E-13). Columns (12) and (13) convert these y'_o range values to x values so that they can be plotted on figure E-1.

TABLE E-2. CONFIDENCE BOUND DUE TO RANDOM SAMPLE DEVIATIONS FROM A TRUE LOGNORMAL DISTRIBUTION (METHOD 2)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
k	Accum. Freq. (F)=k/n	Midpoint of F, F'	Z	Repair Times x	$W = \mu' + \sigma' Z$	$\ln x - W = D$	d^2	A (at $Z=Z_o$), use Equation (E-13)	W-A	W+A	x(high)= exp(W-A)	x(lower)= exp(W+A)
1	0.1	0.05	-1.645	0.5	-0.814	0.121	0.015	0.240	-1.054	-0.574	0.349	0.564
2	0.2	0.15	-1.04	0.65	-0.437	0.006	0.000	0.224	-0.661	-0.213	0.516	0.808
3	0.3	0.25	-0.675	0.8	-0.210	-0.013	0.000	0.217	-0.427	+0.007	0.652	1.007
4	0.4	0.35	-0.386	0.9	-0.030	-0.075	0.006	0.214	-0.244	+0.184	0.784	1.202
5	0.5	0.45	-0.125	1.1	+0.133	-0.037	0.001	0.213	-0.080	0.346	0.923	1.413
6	0.6	0.55	0.125	1.25	+0.288	-0.065	0.004	0.213	+0.075	0.501	1.078	1.650
7	0.7	0.65	0.386	1.5	+0.451	-0.045	0.002	0.214	0.237	0.665	1.267	1.944
8	0.8	0.75	0.675	1.8	+0.631	-0.043	0.002	0.217	0.414	0.848	1.513	2.335
9	0.9	0.85	1.04	2.3	+0.858	-0.025	0.001	0.224	+0.634	1.082	1.885	2.950
10	1.0	0.95	1.645	4.1	+1.234	+0.177	0.031	0.240	+0.994	1.474	2.702	4.367

E.4 Comment on Figure E-1 and the Procedure for Combining Methods 1 and 2

After observing the regression line confidence bounds shown in figure E-1, we can see that the method 2 prediction is effective only in predicting the confidence interval for the noise effect alone. According to table E-2, column (9), the A values are nearly constant, which is roughly equivalent to the product of $t_{\alpha/2}(n-2, _{d.f.})$ and $\hat{\sigma}_{\varepsilon}$.* As a sample size (n) increases, this phenomenon will be even more noticeable. This is because table E-2, column (9) data is computed assuming $\hat{\mu}'$, $\hat{\sigma}'$ are constants so that the computed A value will predict the range of y'_o (which is a subset of Y'_o) at a given confidence level. If equation (E-13) is modified to predict the confidence interval of Y'_o instead of y'_o, the worst expected combination of maximum ranges of $\hat{\mu}'$ and $\hat{\sigma}'$ values should be used so that the probability

$$(V_L < Y'_o < V_H) = \text{probability}\left\{ \hat{\mu}'_{(\;)} + \hat{\sigma}'_{(\;)} Z_o - A < Y'_o < \hat{\mu}'(\;) + \hat{\sigma}'_{(\;)} Z_o + A) \right\} \geq 1 - \alpha \tag{E-15}$$

*The A value is the repair time interval between confidence bound and regression time.

In this case $\hat{\mu}_{(\ )}$ can be either $\hat{\mu}'_H$ or $\hat{\mu}'_L$, and $\hat{\sigma}'_{(\ )}$ can be either $\hat{\sigma}'_H$ or $\hat{\sigma}'_L$ depending on which combination provides the maximum range of Y'_o. The rules for selecting the proper pair of $\hat{\mu}'$ and $\hat{\sigma}'$ limits are as follows:

$$V_H = \ln\hat{X}\ (\text{upper}) + A = \hat{\mu}'_H + Z_o(\hat{\sigma}'_H) + A \text{ for } Z_o \geq 0 \quad \text{(E-16)}$$

$$V_H = \ln\hat{X}\ (\text{upper}) + A = \hat{\mu}'_H + Z_o(\hat{\sigma}'_L) + A \text{ for } Z_o \leq 0 \quad \text{(E-17)}$$

$$V_L = \ln\hat{X}\ (\text{lower}) - A = \hat{\mu}'_L + Z_o(\hat{\sigma}'_L) - A \text{ for } Z_o \geq 0 \quad \text{(E-18)}$$

$$V_L = \ln\hat{X}\ (\text{lower}) - A = \hat{\mu}'_L + Z_o(\hat{\sigma}'_H) - A \text{ for } Z_o \leq 0 \quad \text{(E-19)}$$

This rule is identified with that shown in equations (E-6) and (E-7).

Since the value of $\hat{\mu}'_H$, $\hat{\mu}'_L$, $\hat{\sigma}'_H$ and $\hat{\sigma}'_L$ can be estimated by equations (E-4) and (E-5), and $\hat{A}'_R$ value can be estimated by equation (E-13), the confidence bound predicted by equation (E-15) is equivalent to the combined results of Methods 1 and 2. To illustrate how combined Methods 1 and 2 can be used, table E-3 is constructed. The procedures for computing the data in table E-3 are explained as follows:

Column (1) and (2) data are obtained from table E-1 or E-2, columns (3) and (4).

To estimate the data in row 1 of columns (3) and (4):

$\hat{\mu}'_H$ (from page 7-8 computation) = 0.483

$\hat{\sigma}'_L$ (from page 7-8 computation) = 0.487

A (from table E-2, row 1, column (9)) = 0.240

$V_H = 0.483 - 1.645\ (0.487) + 0.240 = -0.078$

$\hat{\mu}'_L$ (from page 7-7 computation) = -0.062

$\hat{\sigma}'_H$ (from page 7-8 computation) = 0.915

$V_L = \mu'_L - 1.645(\sigma'_H) - 0.240 = -1.807$

To estimate the data in row 1 of columns (5) and (6):

$\hat{X}_{high} = \exp\ (V_H) = \exp\ (-0.078) = 0.925$

$\hat{X}_{low} = \exp\ (V_L) = \exp\ (-1.807) = 0.164$

TABLE E-3. COMBINED METHODS 1 AND 2 CONFIDENCE BOUND PREDICTION

(1)	(2)	(3)	(4)	(5)	(6)
F'	Z	V_H = lnX (upper) + A	V_L = lnX (lower) - A	Combined $\hat{X}_{high}$ = exp V_H	Combined $\hat{X}_{low}$ = exp V_L
0.05	-1.645	-0.078	-1.807	0.925	0.164
0.15	-1.04	+0.200	-1.237	1.221	0.290
0.25	-0.675	+0.371	-0.897	1.449	0.408
0.35	-0.386	0.509	-0.629	1.663	0.533
0.45	-0.125	0.634	-0.389	1.886	0.678
0.55	0.125	0.810	-0.214	2.247	0.808
0.65	0.386	1.050	-0.088	2.857	0.916
0.75	0.675	1.317	0.050	3.733	1.051
0.85	1.04	1.658	0.221	5.248	1.247
0.95	1.645	2.227	0.499	9.276	1.647

E.4.1 Final Comment on Combined Methods 1 and 2. Note that α used in method 1 (table E-1) is 20 percent while α used in method 2 (table E-2) is 5 percent. Proof that these methods are compatible is that according to equation (E-8), the ultimate confidence level of method 1 is 1 - $(20\%)^2$, or 96 percent, while that by method 2 is 1 - (5%), or 95 percent. Since ε defined by equation (E-10) is independent of μ' and σ', the combined confidence level according to equation (E-15) should be equal to or greater than 95 percent.